The Central Valley Project

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P. 35, l. 1, *for* "6 per cent" *read* "60 per cent."

P. 71, l. 11, *for* "700" *read* "70,000."

P. 108, l. 26, *for* "75-kilowatt" *read* "75,000-kilowatt."

P. 123, l. 1; p. 137, l. 34; and p. 138, l. 3, *for* "560" *read* "602."

P. 135, picture legend, *for* "Boulder Dam (upper view)" *read* "Stony Gorge Dam (upper view)"; and *for* "Stony Gorge Dam (lower)" *read* "Boulder Dam (lower)."

P. 139, l. 5, *for* "as" *read* "at."

THE CENTRAL VALLEY PROJECT

The
CENTRAL VALLEY PROJECT

Compiled by

WORKERS OF THE WRITERS' PROGRAM

of the

WORK PROJECT ADMINISTRATION

in Northern California

Sponsored by

CALIFORNIA STATE DEPARTMENT OF EDUCATION

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FOREWORD

The story of the Central Valley Project is of the deepest interest to Californians. In order that the children of the state may have firsthand information about an undertaking that so profoundly affects the welfare of every citizen, this publication, *The Central Valley Project,* has been prepared by the Northern California Writers' Program of the Work Projects Administration. The manuscript was verified by the Bureau of Reclamation, United States Department of the Interior, the agency which is responsible for the construction of the Central Valley Project.

Helen Heffernan, Chief, Division of Elementary Education, has represented the State Department of Education which has acted as sponsor for the Northern California Writers' Project. She has planned this entire publication.

The enterprise that has resulted in this publication is particularly noteworthy at a time when all thinking citizens are directing their attention toward every form of co-operation that will weld our efforts into a dynamic unity. Four independent agencies, the United States Bureau of Reclamation, the Work Projects Administration, the University of California, and the California State Department of Education, have utilized the techniques of co-operation to produce this bulletin. This bulletin has great informational value, and furthermore its use in the schools will provide for the children of California an outstanding example of the service of government to the citizens of a democracy.

Walter F Dexter

Superintendent of Public Instruction

UNITED STATES DEPARTMENT OF THE INTERIOR

HAROLD L. ICKES, *Secretary*

BUREAU OF RECLAMATION

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The Central Valley Project is being built and is to be operated by the United States Bureau of Reclamation, which furnished many of the data and all of the photographs for this book.

PREFACE

Of all California's achievements, the Central Valley Project is likely to affect the daily lives of more people than any other. For nearly a hundred years California's Great Valley—heart of its rich agricultural empire—has suffered from both flood and drought. The Central Valley Project will alleviate both evils. It will spare this region the effects of too much water and too little, by remaking the landscape, redistributing rivers over the valley's whole 500-mile length, storing up water in the wet regions and releasing it in the dry. The benefits will reach millions of people.

This is the story of the Central Valley Project. It has been written for the teachers and students of California's public schools. In the writing of it, we have hoped that it may interest a wider audience as well.

In the preparation of the book, we have been indebted especially to the sponsor's representative, Helen Heffernan, Chief of the Division of Elementary Education of the State Department of Education, at whose suggestion it was undertaken, for her generous advice and assistance.

For their helpful co-operation, our thanks are due R. S. Calland, Acting Supervising Engineer; C. C. Anderson, Office Engineer for Shasta Dam; O. G. Boden, Construction Engineer in the Delta Division; W. A. Dexheimer, Chief Inspector for Shasta Dam; and Phil Dickinson, Director of Information for the Central Valley Project—all of the United States Bureau of Reclamation. We are grateful for the assistance of Professor E. R. Davis of the Department of Engineering Materials and Professor M. C. Kruger of the Department of Forestry of the University of California, and Edith Schofield, Regional Librarian of the United States Forest Service. We wish also to thank for their kind help C. Binns, General Electric Company, San Francisco; H. G. Brann, Santa Cruz Portland Cement Com-

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The Central Valley Project has been a joint undertaking of the San Francisco and Oakland units of the Northern California Writers' Program, the former supervised by Katherine Justice and the latter by Willis Foster, under the supervision of Margaret Wilkins, State Editorial Supervisor, and Paul C. Johnson, State Research Supervisor. The writing of the first draft was chiefly the work of Marc Bliss, Dean Beshlich, and Wellwood Condé, aided in research by John Delgado, Charles Egan, Howard Hoffman, and other members of both units. The final draft was written chiefly by Wellwood Condé, Gladys Pittman, and Amy Schechter, under the latter's direction.

WALTER MCELROY
State Supervisor, Northern California Writers' Program

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Part I
THE GREAT VALLEY

MT. SHASTA—These snowy slopes supply water for Central Valley farms and cities.

THE THREAT OF DROUGHT AND FLOOD

Ninety years ago, canvas-covered wagon trains crawling slowly westward lurched clumsily to the top of the high mountain wall that separates the scraggy sagebrush acres of Nevada from the green pastures of the western foothills of the Sierra Nevada. At the feet of the eager Argonauts lay cool, dark forests, mountain meadows, and beyond, the rounded hills that tumble down in dwindling cadence to the flat, brown floor of the valley of the San Joaquin. It was sere and uninviting, a vast expanse of desert, with strips of green showing only along the streams and rivers; and the people pushed across it, hurrying to the seacoast or rushing northward to the mines.

Gold was the magnet that drew these thousands over the dusty trails across the continent. Gold dust, gold nuggets, gold bars. But there was gold as well in the rich black earth churned up by the creaking wagon wheels. Many a canny farmer picked up a handful of the soil, crumbled it, and gazed speculatively at the wide, smooth valley. "Good growing ground—if it gets water!"

So they settled along the creeks and rivers. They built their homes. They planted grain and fruit trees and vineyards and they tapped the streams and dug long ditches to water their thirsty crops. As the valley filled with farmers, they drew away from the watercourses; and gaunt windmills dotted the valley floor, drawing up the water that greened the fields and made the once-dry desert an agricultural empire.

But in this paradise there was always a faint anxiety, like a spiral cloud on the far horizon—"if it gets water!" In 1864, during the winter season when heavy rains usually soaked into the parched earth, farmers and cattlemen scanned bright skies for signs of showers. Then it was 1866—the third dry year.

November, December, January, and February passed, and almost every day the sun rose over the drying earth. Virtually no snow fell in the mountains, and streams and river beds showed cracked, scaly cakes of dirt. The grass dried up. Livestock grew thinner and weaker as the animals cropped the hillsides to the bare earth and lowed for water. Still very little rain came, and the carcasses of thousands of cattle strewed the bare plain. The farmers scratched faintly at the hard-packed ground with their plows and seeded the shallow furrows. The nights were clear, the days were hot and dry, and almost nothing grew.

This was the great drought of 1864-66—the most destructive in California history—when winter downpours were strangely lacking, when no spring freshets from melting mountain snows came down to the river. The whole great, fertile valley was without water.

The farmers remembered those days of terror. The decade-long search for water began. Canals and ditches threaded the farm lands. Wells were bored to the underground reservoirs, seepage from rains and streams and water channels, far beneath the surface.

The years passed.

Swift streams, tributaries of the San Joaquin that once filled ditches in the cultivated lands, were growing smaller as their flow was used by more farmers over wider, drier acres. In the southern part of the valley, wells gave out and expensive machinery reached as much as three hundred feet into the earth to find water for the miles of orchards, vineyards, and the truck, forage, cereal, and cotton crops. At the northern reaches of the San Joaquin, where sediment from uncontrolled winter floods and debris from long-forgotten mining claims had clogged the channel and raised the river bed within its protective levees higher than the delta lands through which it flows, the current slowed. Salt water from Suisun Bay crept up the river, fouling wells and killing crops.

In parts of the valley, farmers whose grandfathers had watered the sunburned desert and made a garden watched their

vineyards gray and droop for lack of moisture. Orange and lemon groves, where fruit once hung heavy on blue-green branches like gilt globes on a Christmas tree, turned dusty brown. Machinery to raise water from that sinking underground water level costs money. With meager crops, the farmers didn't have it.

Some of them cut their planted acreage in half, hopeful that the water would irrigate that much of a crop. They chopped the dry and dying orchards into firewood, and weeds and thistles sprouted in the rows between the stumps.

Now the valley floor is spotted with abandoned farms. Willows droop inert over the banks of an irrigation ditch whose water has shrunk to a muddy trickle. Here paint scales from an empty farmhouse. Jimson weeds grow in the walks and lean boldly against the deserted threshold. Lizards bask in the sunlight at the concrete base of the waterless well, and cows munch the straggly grass in a dried-out alfalfa field.

In the southern San Joaquin Valley, 400,000 acres of the richest farmland in the state is threatened by this diminishing supply of water. Surveys have shown that there is a local water supply available for only half that acreage. Unless relief is soon forthcoming, 200,000 acres will again be desert. But the land is still black and rich. In the words of the first settlers, it is still "good growing ground—if it gets water!"

Conversely, in the Sacramento Valley to the north, for generations, floods that washed out crops, ruined homes, and swept through towns and villages have been the curse of farmers.

Streams crisscross their valley. Under gentle, winter showers they fill irrigation ditches, inundate the rice lands, store water in the reservoirs beneath the earth. Down the center of the valley for 350 miles flows the Sacramento, greatest of California's rivers.

Sometimes, when spring snows melting in the mountains or heavy winter rains fill the channels of the creeks and rivers that find outlet in the Sacramento, that normally peaceful giant

strains at confining banks and levees. It grows stronger and more vicious as brush- and silt-laden waters pour into its rushing torrent. It gnaws greedily at dikes, bites great chunks out of man-made barricades, and with a roar like a prehistoric monster crashes through its barriers to devastate the countryside.

It is spring, 1940. In the mountains, high above the timber line, melting snows are swelling streams. Threatening, overcast skies suddenly let loose their burden of moisture over the valley.

Rain falls in sheets, hour after hour, day after day, without ceasing. In the Sacramento River rampant water laps at the levee tops. Farmers and townspeople in the lowlands pack possessions, with fear-filled faces. Mounted ranchers round up cattle, driving, beating them towards the foothills. Guards patrol the levees and watch the rising waters with anxious eyes.

The river sucks at the earth barrier.

Boys from CCC camps bolster the weakening dikes with sand-filled sacks. Farmers with their tractors and their scrapers work feverishly to raise the walls and fill crevasses.

By radio, by telephone, up and down the valley, crackle warnings to more isolated farms.

"The river is rising! Leave immediately for higher ground!"

Cars and wagons loaded with women and children, pets, and furniture, hurry down the slippery highways.

Like a maddened animal the swirling, muddy torrent rips out bridges, uproots trees, licks hungrily at the sandbag reinforcements. Here and there a tiny wave breaks over the embankment. A trickle through a gopher hole grows wider. The levee crumbles. A racing current floods an orchard, inundates a farm, rushes down the main street of the valley town. Water plays with motorcars, marooned, deserted, on the roadways.

At the Modoc County Hospital white-clad surgeons racing against time finish operations. Nurses quiet frightened patients.

Still the rain comes down.

The river presses on the dikes around a city.

A muffled roar!—dynamite!

Above the threatened town, workers blast the levees.

A wave of wild water rising to a 20-foot crest rushes over cultivated fields. It cracks against and topples an evacuated farmhouse. It tears down poles and fences, gouges holes in concrete roads, and finally, spending its fury, flattens itself into a shallow inland sea.

Airplanes search for signs of life over the watery wastelands. Power craft and Coast Guard surf boats from San Francisco—trucked into the flooded areas—cruise over drowned fields and submerged highways looking for families trapped by the dirty water. Dead pigs, cows, barnyard fowl, and wild game float by.

A levee worker, his wife and children, overtaken in their car by the muddy tide, hail rescuers from the branches of a draggled oak tree. Beneath them all night long the river has been thrusting up its yellow fingers. Ten feet of water eddies around the sturdy trunk.

The rain has stopped. The sun comes out, and slowly the rivers crawl back to their ravaged channels.

The Red Cross and the state agencies begin their work of salvage. The storm has left 200,000 acres of flooded farm land. Rocks and boulders litter orchards. Black, rich earth is washed away. Seed stocks are ruined. There will be no spring crops for thousands of farmers. Wells and springs are choked with filth and rubbish; drinking water is polluted.

In the mountains, slides block roads and railroad tracks. Trestles are undermined, trains have to be rerouted. Telephone and power lines are down. Hundreds of families return to their homes to dig out muck and silt and repair damage.

The danger is past, but more than fifteen million dollars is the cost to the state of this one flood in the Sacramento River Valley.

So the farmer in the northern portion of this 500-mile-long valley is deluged with water, while his brother in the south watches his crops dry and die for lack of it.

It is misplaced rain! "Too much in the wrong places, or too little in the right places, and never in the right season." Several million acres of valley land have suffered from extremes in moisture since long before its recorded history. Ancient Indian legends tell of a year of drought when not a drop of water fell in the sun-baked valley. They tell, too, of a year when the rains came down and the valley was a mammoth, rock-rimmed lake that stretched from the Sierra Nevada to the Coast Range.

The clamor of the farmers for water or for the regulation of it is being answered. The United States Government is building two major dams. Shasta Dam on the north will catch and hold those raging winter torrents. Friant Dam, in the south, will imprison the San Joaquin. Miles of canals and channels leading from the dams through the valleys as far south as Bakersfield will bring water to those thirsty acres where wells are drying and the water table is dropping daily to dangerously low levels.

Technical and difficult the problem seems—a challenge to the elements, a regulation of the seasons. And it is just that. The best description of the engineering feat that will distribute water now flooding the Sacramento Valley to the acres now turning to desert in the San Joaquin was given by a workman on the Shasta Dam. Asked what he was doing, he looked up from his pneumatic drill and answered, "Mister, I'm moving the rain!"

BIRD'S-EYE VIEW

If the Sierra Nevada Mountains form the backbone of California, the great Central Valley is its living heart, a writer has said.

Farming, on an immense scale never before known, is the key industry of California. Everyone knows how very important the huge motion-picture industry in Hollywood is; but the fruits and vegetables and cotton and hay grown in California bring in more money than the motion pictures every year, and much more than oil and gold together. Just this one state pro-

duces half of all the country's fresh fruit, almost all of its dried fruit, a third of its truck crops, and a third of its canned fruits and vegetables.

More airplanes are made in California than anywhere else in the country; other manufacturing industries are growing steadily; but farming is still the center of California's life. Refrigerator cars wait on special sidings on the great ranches to rush peaches and plums and grapes packed and handled as carefully as rare fragile china to cities across the continent or to San Francisco and Los Angeles for transshipment to far lands. The greatest part of all the cargoes of the swift ocean liners and grimy salt-caked freighters that come to anchor in California harbors, in peacetime, is produce from her inland valleys. Miles of shiny new cans are manufactured each year for fruit and vegetable canneries; lumber mills turn out millions of feet of boards for crates and boxes; paper mills make cardboard cartons; and San Francisco's big job-printing industry prints immense numbers of labels for cans.

If farm crops fail, if once fertile acres dry up into desert land for lack of water, shipping and railroad and truck transportation and many great industries with their tens of thousands of workmen and the banks that finance industry all suffer the effects.

California has many farming areas besides the great Central Valley—the vine-covered foothills; Salinas Valley, called the Valley of Green Gold because of its vast million-dollar green lettuce fields; Santa Clara Valley with the massed blossoms of its fruit orchards; the region south of the rocky barrier of the Tehachapi where the great citrus industry of the state centers; the rich irrigated acres reclaimed from the burning desert in the Imperial and Coachella valleys far down toward the Mexican border.

But the great Central Valley, stretching 500 miles vast and level down the center of the state like a giant's dance floor, walled in by high mountains, slashed by California's two biggest streams, is the greatest of them all. From an area larger than

all England, its groves and orchards, fields and farms and vineyards pour out their products on the markets of the world. It produces more than all the other farming regions in California put together. Three-quarters of all the world's supply of grapes and raisins and dried fruits and a quarter of all the vegetables that all the families and restaurants use in the United States come from the Great Valley.

More than a million people live in the valley. There are over 40,000 farms and ranches, among them a number of the largest in the world, and the barbed wire fencing them in is enough to encircle the country completely. Eighty-three cities and towns and villages line the broad highways unrolling like endless ribbons north and south and dot the network of roads crisscrossing the valley. You can travel through the valley all day and see nothing but an unbounded plain stretching on all sides to the horizon. But actually it is completely surrounded by lofty mountains except for the one break in the craggy wall where the San Joaquin River, flowing north, and the Sacramento River, flowing south, meet at the western barrier of the valley and join waters above San Francisco Bay as they sweep through to the Pacific Ocean beyond.

At the head of the valley, far to the north near the Oregon line, Mount Shasta, lofty and crowned with year-round snow, rises in solitary grandeur from the dark green forest at its base. On the east side the slopes of the wild Sierra Nevada hem in the valley. On the west the Coast Range turns bold gray cliffs to the tireless battering of huge Pacific breakers and on the valley side descends more gently in rolling brush-covered foothills to the plain.

The Great Valley is really two valleys—the valley of the Sacramento River to the north, the valley of the San Joaquin River to the south. The two river basins come together in the marshy delta region where the two streams, joining on their way to the sea, cut up the land into hundreds of islands with fat, black peat soil where rice grows under water as in China and most of the country's asparagus and celery is raised.

The San Joaquin Valley, by far the larger, contains about two-thirds of the Great Valley's 10,000,000 acres of agricultural land—land that is now being farmed or that could be farmed with proper irrigation and improvement; the Sacramento Valley contains about one-third. The areas that actually have been brought under irrigation, including those parts which are today in danger of becoming desert land again, amount to three million acres, divided between the San Joaquin and Sacramento valleys in about the same proportion of two-thirds and one-third.

The bulk of the farm land that needs water to go on producing crops every year thus lies south, in the San Joaquin Valley. From this condition comes the difficult problem that has faced California's farmers for years: the bulk of the water available for irrigating these crops lies north, in the Sacramento Valley. The situation has been described by a leading engineer of the United States Bureau of Reclamation, which is handling the immense job of solving the Great Valley's water problem through construction of the Central Valley Project, as demanding the greatest water-conservation plan since time began.

He put the problem in the engineer's sharp, clear way that is easy to remember: "In the Central Valley, two-thirds of the water runs off in the Sacramento, and one-third in the San Joaquin, while some two-thirds of the irrigation demands are in the San Joaquin Valley as against one-third in the Sacramento Valley. That immediately calls for readjustment."

In other words, there is enough water to keep the fields green and the orchards blooming, but it is distributed in a topsy-turvy manner. The water problem has also another very important phase: the timing of the waterflow. By far the larger part of the yearly water supply becomes available in winter and spring months when the demand is lightest, and only a small part in the hot searing summer when the need is desperate.

It is important to understand the background of the great struggle for water in the Central Valley, heroic and exciting as any motion picture ever produced. A part of that background is

the geological history of the valley, the story of how the valley and the mountain barriers surrounding it and the rivers that water it were formed far back at the dawn of the world, long before man appeared upon the earth.

THE VALLEY COMES INTO BEING

Millions of years ago, so many millions that scientists can not agree on just how many, most of the land that is now California was under the sea. Even the Sierra Nevada was covered with brackish salt water. Of all the California mountains, only the Klamath peaks, higher and more rugged than they are today, had been pushed above the sea by terrific movements and explosions below the earth's crust.

More millions of years passed. A gigantic struggle was taking place beneath the surface of the earth and the sea. Huge masses of rock pushed and strained against one another as they cooled from their molten liquid state until, finally, the Sierra Nevada rose above the water. The floor of the Pacific Ocean sank, and another mass of rock, the Coast Range, pushed out of the ocean. Between the two mountain ranges, the land was forced down and the great Central Valley was formed.

For centuries the valley was flooded with sea water that flowed in through gaps in the slowly rising Coast Range until most of the gaps were closed.

During all this time the surface of the valley was changing. Water vapor drawn from the sea and cleansed of its salt and other impurities was formed into clouds and blown against mountain ranges. Rain fell from the clouds, washing so much of the earth surface from the mountains down into the valley that a thick carpet of rich alluvial soil was gradually laid down over the valley floor. Recent borings deep down into the soil of the great Central Valley have shown that so much earth has been washed into the center of the valley since the days when it was first being formed that a hole dug down to the original bedrock could hold sixty of the highest buildings in California, one on top of another, without the top one showing above the ground.

As the mountains rose, great changes were made in them. The original masses of rock were twisted and wrenched apart, and between the fissures flowed molten rock from below the earth's crust. This rock cooled to form gold-bearing quartz and other rock forms.

In the summer, heat swelled the surface rocks. Cold rains fell, shrinking the rocks so fast that they cracked, just as a hot glass will crack if cold water is poured into it too quickly. In the winter, rain froze in the cracks and the ice swelled them wider until pieces of rock were broken off. Torrents of rain washed them down toward the valley, rubbing them together and changing them to the gravel and fine soil that raised the valley's floor.

At first the rivers formed by the rain emptied into a chain of lakes in the lowest part of the valley. In time, trees, sweet grasses, and flowers began to grow along the borders of the lakes and rivers, nourished by the rich soil and the fresh water.

Mastodons, the huge ancestors of the modern elephant, giant wolves, and fierce saber-tooth tigers roamed the valley plains where only sea animals and reptiles had lived before.

Always the rivers rushed down the sides of the Sierra Nevada and the Klamath and Coast ranges, filling the lakes with silt and gravel until most of them could no longer hold any water. Immense glaciers, slow-moving bodies of thick ice and snow, covered the Sierra, scraping great gouges and chunks out of the face of the rock. When the glaciers melted, new torrents of water with their burden of earth rushed down toward sea level across the valley.

After the lakes were filled, the water found its outlet in two great river channels. One of them, the Sacramento, ran in a general southerly direction, fed by east-flowing streams of the Coast Range, the rivers of the Klamath Range, and the westward-draining waters of the Sierra. From the south came the San Joaquin River to meet the Sacramento and flow with it to meet the ocean in Suisun Bay.

All this time, while the rivers were being formed, life was changing in the valley. Smaller and swifter animals, more like

the ones we know today, were developing because of the need to escape or to hide from their enemies. These smaller animals, too, were better able to live because they needed less food.

Still the surface of the valley kept rising. And each spring, when the melting snows in the mountains added water to the winter rains, the rivers were flooded and their load of soil spread out over the valley floor, building up the rich acres of the great Central Valley which was to become one of the most fertile growing areas in the world. Some years the entire valley was flooded, with only the Sutter Buttes remaining above the water. The Sutter Buttes are those strange, sharply pointed hills like volcanos that appear to the north of Marysville today—the only hills rising out of the whole great flat stretch of the Sacramento Valley.

Below the drainage basin of the San Joaquin River, shorter rivers spread their entire loads of soil out from the mountain gorges in the shapes of fans with their narrow ends pointed toward the mountains. One of these alluvial fans, formed by the Kern River, stretches clear across the southern end of the valley. The Kings River, unable to find an outlet to the sea, poured its waters into the Tulare Lake basin.

This short account of how the valley was formed will make it easier to understand where the valley's water supply comes from and how it is distributed—all a part of the problem of controlling and directing the state's water resources that the Central Valley Project will help to solve.

SOURCES OF WATER

Almost all the water of the Great Valley comes from the Sierra Nevada. The greatest sources are the Sacramento, San Joaquin, Kings, and Kern rivers.

The Sacramento is fed by a number of mountain streams and rivers, some of them rising far to the north in the Trinity and Warner mountains. Among its tributary streams are the Pit, the Fall, and the McCloud, the Feather and the Yuba, the Bear and the American rivers. About 21,000 square miles are

WATER IS LIFE—The valley's most important resource, water, originates largely in the snow banks of the high Sierra (above), cascades down the mountains in rushing streams (right), and flows on toward the sea in broad rivers (below) that are used for navigation, irrigation, and many other purposes.

RELIEF MAP OF CALIFORNIA—The great Central Valley is clearly shown in the interior of California, bounded on the west by the Coast Ranges, and on the east by the Sierra Nevada. The valley's rivers are like a system of arteries, the main streams of which are the Sacramento in the north and the San Joaquin in the south, running together in the middle or delta area of the valley and issuing out through San Francisco Bay to the Pacific Ocean.

drained by these streams and their branches, flowing south and west. The Sacramento itself flows southward about 320 miles.

The San Joaquin, flowing south, then southwest, and then north to empty into Suisun Bay near the mouth of the Sacramento, is some five miles longer. It rises among the Sierra Nevada peaks that wall the central part of the state, where its main tributaries—the Fresno, Merced, Tuolumne, Stanislaus, Calaveras, and Mokelumne rivers—also have their sources. It drains a total area of 14,000 square miles.

The Kings and the Kern rivers both spring from glacial lakes high among lofty slopes of the southern Sierra, draining 4,100 square miles of watershed. They flow south and west, the Kings emptying into Tulare Lake and the Kern into a reservoir located at the former site of the Buena Vista Lake.

Every year a huge volume of water falls in the form of rain or snow on the mountain chains which form the Central Valley's watersheds. And yet every year hundreds of valley farms suffer for lack of water.

What is the explanation?

The wet winter winds that rush across California carry along with them the water that falls in the form of snow and rain. Each year these powerful servants of nature bear three hundred billion tons of water across the state on their mighty shoulders. Sweeping along, the storm winds hurl the myriad droplets suspended in the air against the mountain slopes. Heavy rains running off as soon as they fall bring the swift and violent winter floods that scourge the Sacramento and sometimes the San Joaquin Valley. The water that falls as snow lies quiet for awhile, blanketing the higher slopes and peaks, or piles up in great drifts in the mountain gullies. The spring floods come when the snows on the lower slopes of the Sierra melt, reaching their peak in May and June; still later, the snow melts on the highest crags where the temperature is colder.

Thousands of runlets and rills and streams and mountain brooks flow down the mountainsides, uniting into raging tor-

rents that surge and roar through high-walled canyons and tumble in wild, white foam over rocky rapids and waterfalls.

The pace of the rushing streams slows as they near the level valleys. Stream joins with stream to form the valley's two great rivers. Onward they flow across the plains, joining as they reach Suisun Bay, and on through Carquinez Strait and San Francisco Bay till they reach the ocean. And here the waters return to the source from which they came.

In springtime the Sierra Nevada is actually an incredibly huge storehouse of water in the form of snow. Enough water is stored there, according to the calculations of scientists, to cover all the 10,000,000 acres of irrigable land in the Central Valley to a depth of four feet, enough to turn the whole valley into a fertile paradise. But today valley lands benefit by only a small fraction of this great water reservoir. By far the larger part never reaches the valley farm lands at all, but rushes unused headlong to the ocean within ninety days after it has fallen.

The Central Valley Project will undertake to bridle these torrents and lead them into the broad acres down in the southern valley that drought is changing from a brilliant crazy quilt of many-colored patches of garden, orchard, and field to a dreary waste of parched and dusty earth.

In the summer, moisture in every form evaporates at a rapid rate in the hot, dry valley. The smaller streams disappear altogether. Even the Sacramento and San Joaquin rivers dwindle to dangerously low levels. The valley irrigation systems that depend on these rivers for their supply run out of water. In the delta area their weakened flow causes another extremely serious condition to develop.

Here the streamflow is no longer powerful enough to form an effective fresh-water barrier to the salt water sweeping in from the ocean. Salt water backs up from Suisun Bay, into which the rivers pour toward the ocean, and enters the delta channels and ditches. The results are disastrous to farming in the area because salt water makes the soil unfit for crops.

Besides killing valuable crops the salt water hampers the many important industries of the Contra Costa County region along the shores of Suisun Bay. Canneries, sugar and oil refineries, steel plants, and other large enterprises—in which nearly $50,000,000 have been invested—require fresh water in large quantities for their operations. A single plant uses more than a million gallons a day. Some factories even have been forced to send barges as far as 25 miles upstream, beyond the area of the creeping salt-water invasion, to bring back fresh water.

A small—but important portion of the valley water supply—does not flow down the mountainsides and into the rivers, but instead finds its way into underground basins beneath the valley floor. Some of the water that falls on the earth as rain or snow seeps into cracks and seams in rock and soil and, instead of running off, is slowly drawn downward by the constant pull of gravity. The waters that follow this slow and devious course are only a fraction of the total, but they help to increase the dry-season flow of valley streams. More important, they feed the springs that farmers in the drier areas tap when they sink wells to irrigate their lands where irrigation canals and ditches are not available.

THE FIRST MEN

It is impossible to say just when man first came into the valley. Some scientists say that it was more than fifteen thousand years ago, but it may have been much longer than that.

The first California men did not make any great change in the valley. Neither did the Indians who inhabited the valley many centuries after them. Deer and elk and fish were plentiful, and wild grapes and the acorns out of which the Indians made flour grew close at hand. The red men lived by hunting and fishing. There was no need for them to raise crops to satisfy their simple needs. They stayed close to the rivers and the lakes, wearing narrow paths along the banks and paddling over the waters in raftlike tule balsas and square-ended dugout canoes.

The first white man to sail into a port in the territory that now is California was the Portuguese, Juan Rodríguez Cabrillo, seeking, in the service of New Spain, a direct passage to the fabulous riches of eastern lands.

According to the remarkable record of Cabrillo's travels, written before he anchored in the fine land-locked harbor now known as San Diego, in 1542, he skirted a shore line where "mountains . . . reach the sky, and the sea beats upon them." But winds and high seas held the little craft offshore. Cabrillo sailed past the headlands of the Golden Gate without seeing the passage that gave entrance to the Bay of San Francisco and the westward-flowing channel of the Sacramento and the San Joaquin.

By 1769 rumors reached the Spanish explorers of the presence of Russian trappers in northern California; and fearful that other nations would stake claims to this great new territory, Spain speeded exploration and settlement of her western outpost. Missions, presidios, and pueblos were established along the coast from San Diego to San Francisco; but for many years little effort was made to explore the territory lying on the other side of the mountain range separating the coastal valleys from the great central plain.

The Franciscan monks who established missions along the coast explored the San Joaquin Valley soon after they came to California but built no missions there because of stories of its wild desert stretches and the warlike character of the Indians who inhabited the interior regions. But the valley was well known to them. The Franciscans and the government troops guarding Spain's new possessions co-operated in sending some twenty expeditions to find good places for building missions in the valley and to bring back neophytes, as the Indians taken into the missions were called.

Spanish soldiers from San Diego tired of garrison life began deserting and making their way into the southern San Joaquin Valley to live. Expeditions sent after them, penetrating the

valley, pushed forward its exploration. The first man of any nation to leave a written report on the valley was the head of one of these searching expeditions, Pedro Fages, *comandante* of Alta California, as California was then called, who entered the valley in 1773.

During the years that followed, many expeditions crossed the hills into the valley. These expeditions saw and named the lakes and streams. But until the close of the eighteenth century few had traversed the heart of the plain even for a short distance.

Before 1805 Gabriel Moraga, Indian fighter and pathfinder, had visited and named the San Joaquin and Kings rivers, naming the former for Saint Joachim and calling the latter *Rio de los Santos Reyes* (River of the Holy King). Under Moraga, in 1806, twenty-five men and Padre Pedro Muñoz made an extensive exploration of the San Joaquin Valley. They approached the plain from San Luis Creek, crossed a slough and named it *Las Mariposas* for the butterflies that hovered over it, named the Merced River *Rio de Nuestra Señora de la Merced* (River of Our Lady of Mercy), and crossed the Stanislaus, Calaveras, and Mokelumne rivers. Up the Kings River, over to the Kern, east to the rust-colored foothills of the Sierra Nevada rode the party, finally leaving the valley through Tejon Pass, the deep fissure in the Tehachapi Range.

In 1808, in the early days of Indian summer, the scout Moraga left Mission San Jose, crossed the San Joaquin at its junction with the Calaveras, and traced the latter stream to its source in the Sierra. He was looking for a site for a mission in the valley. Farther north, the Mokelumne, the Cosumnes, and the American rivers were followed to their gorges in the mountains. He camped on the lower Feather River, calling it and the broad river which it joined farther south, the Sacramento. The present upper Sacramento he called the *Jesus Maria.* Other investigations of the tireless Moraga carried him up the *Arroyo de las Nueces* (Walnut Creek), across Carquinez Strait, and through the Russian River country.

In 1811 occurred the first known navigation of the rivers, when an expedition sailed from San Francisco Bay and traveled a short distance up the San Joaquin and Sacramento.

The last Spanish exploration of the valley was made by Luís Argüello in 1821. He traveled up the right bank of the Sacramento to its northern reaches, turned down the valley of the Eel River, and followed the Coast Range to San Rafael and San Francisco, looking for trespassing foreigners, Russian and English.

A year later, at Monterey, the capital, the flag of Spain was hauled down; and California became a Mexican province. With the collapse of Spain's western empire, American and English trappers began to trickle into the valley.

The first settlers in the territory now known as California, the Spanish padres and soldiers and colonists, had been here some fifty years before they turned to the development of the Central Valley. From the time when the first mission and presidio were established at San Diego in 1769 until 1836, when the first grant was made in the Central Valley, the Spanish had kept to the lands lying along the Pacific. This was chiefly because the occasional ships that touched the shore were the only possible means they had of communicating with Mexico or Spain or the rest of the outside world. The interior valleys were almost unknown desert and wilderness, infested by ferocious wild beasts and inhabited by hostile Indians who were bitter against the intruders in their hunting grounds.

All the most desirable land had been given to missions and the Spanish cattle ranchers by the 1830's, and then colonizers began to go inland. The first settler was José Noriega, granted a tract of 17,712 acres near the site that Brentwood occupies today. Despite many clashes with the Indians, others began establishing ranches on the San Joaquin and its tributary streams; at the same time to the north, on the present site of Sacramento, the Swiss immigrant Captain John Sutter was setting up the kingdom that was shattered a few years later when John Marshall found gold and the gold rush began.

During the Spanish occupation cattle raising was the economic mainstay of everything. The problem of water to grow fruit or vegetables arose only in the missions, where the padres taught the mission Indians to dig the first rough irrigation ditches that were constructed in California. With water provided, they made bold and successful attempts at raising olives and oranges, figs and grapes, and other fruits from seeds and slips that they brought with them from Mexico when they came to tame the wild new land. But like the *rancheros,* they also depended chiefly on cattle raising and the sale of tallow and hides.

After Mexico gained her freedom from Spain many more grants were made—thirty grants in the valley in the period from 1836 to 1846; but not until the American occupation, two years later, began the real settlement of the central plains.

The very first American on record to enter the valley was young Jedediah Smith, famous Rocky Mountain hunter, trapper, and trail blazer, who opened the door to American colonization. He was also the first man of any nationality to enter the valley by the overland route.

The Mexican authorities objected to the presence of Smith and his heavily armed band of sixteen other young men in their province, but permitted them to leave unharmed. Smith led his men out by a purposely roundabout route through the precipitous and perilous Cajón Pass and into the San Joaquin Valley. The trapper-adventurers took their time, spent months trapping beavers and otters on the Tulare and Kern lakes (filled with water in those days), and lived and hunted with friendly Indians of the Kings River region. Gradually, fishing, hunting, and trapping, they leisurely moved down the San Joaquin River. They reached the Stanislaus River in the spring of 1821, and they finally left California over the northern mountains. Smith was back again by the next year, this time in the north, camping on a tributary of the Sacramento, which the Spanish later named *Rio de los Americanos* because these American trappers had stayed there. The river kept the name—the American—and is

famous because gold was discovered along its banks near Coloma in 1848.

Smith took detailed descriptions of the Great Valley back to the East. More important, his glowing accounts of its unlimited riches helped to bring an influx of trappers, moccasined, buckskin-shirted, their horses decked with pelts or eagle feathers —men as colorful as the red-shirted miners who were to succeed them in the westward march. In four years Jedediah Smith took back $200,000 worth of furs to his fur company's headquarters in St. Louis.

Permanent trails brought settlers pouring into the valley, buying, claiming, squatting on the grassy acres that became range for thousands of sleek cattle. Among these were tight-fisted John Marsh, who stocked his Mount Diablo rancho with herds taken in payment for his services as a doctor, and John Augustus Sutter, fur trader and cattleman-farmer, who built an agricultural empire on the lush banks of the American and Sacramento rivers.

A Boston sailor boy, Richard Henry Dana, in 1840 cruised the coast of California in a ship whose master brought cargoes of hides and tallow. In his *Two Years Before the Mast* he wrote, of "the forests . . . the water filled with fish . . . the plains covered with cattle; climate than which there can be no better in all the world . . . with a soil in which corn yields from seventy to eighty fold."

While the emigrant movement was gaining momentum, the first official expedition reached California under Lieutenant Charles Wilkes of the United States Navy, who in 1841 sent a boat party up the Sacramento River to the head of navigation. Wilkes' observations, invaluable in the later acquisition of California, ended when he cast anchor in New York on June 10, 1842, the same day that John C. Frémont and his Army engineers started on an overland trip westward. With Kit Carson, famous scout, Frémont mapped the Rocky Mountains and the Great Basin from the Rockies to the Sierra Nevada, the territory from New Mexico to Oregon, and the valleys of the San Joaquin

and the Sacramento. On one of his expeditions, Frémont accomplished the formidable feat of crossing the silent frozen waste of the Sierra Nevada in midwinter, reaching the friendly haven of Sutter's Fort half frozen, weak from hunger, snow-blind.

Frémont was the last of the pathfinders in California. In 1846, three years after his first visit, the territory became part of the United States. The people living in the Central Valley looked forward to the peaceful development of their land.

STEAMBOATS ON THE RIVERS

California's rivers—supremely important as a source of water to irrigate its farms—also are important from the point of view of navigation.

In the early days of the state, the Sacramento and San Joaquin formed the main waterways connecting San Francisco with the gold camps and the towns and ranches in the valley. But too much water was withdrawn from the San Joaquin for irrigation purposes and too many trees on the mountain slopes were cut down by irresponsible lumbermen. These trees had held the winter snows, allowing them to melt gradually, thus ensuring a steady flow of water that kept the river at a level high enough for navigation much of the year.

The upper Sacramento channel was blocked by the millions of cubic yards of dirt and rock swept down from the mountains in the course of years of hydraulic mining. Regular year-round navigation became impossible beyond the capital city. Boats disappeared altogether from the San Joaquin River beyond Stockton. United States Army Engineers, giving their support to the Central Valley Project, were especially interested in the question of improving navigation in this part of the country. When the project is completed, the Sacramento and San Joaquin again will form one of the greatest of the inland waterways in the nation.

The discovery of gold in 1848 suddenly focused attention of the country on these rivers. A tremendous shipping boom

developed almost overnight. As news of the discovery spread, hundreds and thousands of men from the rest of the state and the nation swarmed into the Central Valley, and transportation was at a premium. The editor of the *California Star,* just before closing his own plant to search for gold, wrote: "The whole country from San Francisco to Los Angeles and from the seashore to the base of the Sierra Nevada resounds to the sordid cry of GOLD! GOLD! GOLD! . . . The fields are left half-planted, the houses half-built. Everything is neglected but the manufacture of shovels and pickaxes and the means of transportation to Captain Sutter's Valley." [1]

Prices for craft able to navigate the sharp curves and hidden snags of the rivers skyrocketed. Steam launches sold for as much as $35,000. Practically every boat in San Francisco harbor, new or old, was placed on the river run. Steamers from the Atlantic Coast touching at San Francisco went on up the Sacramento River and even up its tributary Feather River. The *Sitka,* her wheelhouse and superstructure washed away, was sold for $15,000 per ton. Eager gold seekers paid from thirty-two to fifty dollars fare to Sacramento and Stockton. The available boats were loaded with provisions for the miners and for trading posts mushrooming into towns and cities near the richest mines.

Passengers were sandwiched between the crates and slept on the lumber on deck or in the holds. Those who had arrived in San Francisco with money wore brilliant new shirts and high-laced boots and carried shiny equipment on their backs. Some, who had no money except for their fares, were dressed in old clothes. On the boats bound for the mining towns were actors and actresses, gamblers, entertainers, and confidence men.

In April, 1849, the *Whicon* made the trip to Sutter's Embarcadero, proving that medium-sized sailing vessels could ascend the Sacramento. Square-rigged ships, barks, brigs, schooners, and tugboats quickly followed as the demand for transportation increased. A famous captain of gold-rush days,

[1] Julian Dana, *The Sacramento, River of Gold.* New York: Farrar & Rinehart, Inc., 1939, pp. 117-118.

SACRAMENTO RIVER—In the winter and spring (upper view) this river has too much water; but in the summer and fall (lower) not enough. The flow needs to be regulated, which is a job for Shasta Dam.

UNCONTROLLED WATER—Floods often bring havoc to valley farms and towns. Shasta and Friant dams will hold back the excess waters for beneficial use in the dry months.

George Coffin, has left us a vivid picture of traffic on the Sacramento River in those hectic years. "Both banks are so overgrown with huge oak and sycamore trees . . . that it is impossible for the wind to find its way through, and there we lay . . . while the tops of the trees are dancing in a stiff breeze," [1] he wrote, describing his 35-day trip up to Marysville from San Francisco.

The solution was to warp and tie—a process by which one end of a long line was tied to a tree while the captain and crew tugged at the other end, the captain holding the tiller between his knees.

Navigation was not the only problem, Captain Coffin wrote. "Now the sun is glaring, the air is suffocating, and the mosquitoes, with fresh-sharpened stilettos, are as greedy as sharks." [2] Progress by sail was so slow that many captains must have echoed Coffin's words: "One hundred and fifty miles of this sort of navigation! I have undertaken a pretty . . . job, to be sure! . . . Sun shining down in a blaze of fury, with not a cloud to screen his scorching rays; thermometer 110 degrees, not a breath to cool our frizzling livers." [3]

By the latter part of 1849 steamships began replacing the wind-driven vessels. The *Sacramento,* brought round the Horn in sections and assembled in San Francisco, made its maiden voyage in September. One of the largest steamers on the river was the *Senator,* a 750-ton vessel sailed here from New York. Upon its arrival the owners declined an offer of $250,000, a wise decision according to a contemporary, who stated that "the *Senator* had carried enough gold from Sacramento to San Francisco to sink her two or three times over with the weight of the precious metal. Add to this the passage and freight money . . . [and] it would probably take two or three similar steamers to convey the freighted gold and . . . coin she has earned for her owners . . ." [4]

[1] Rockwell D. Hunt and William S. Ament, *Oxcart to Airplane.* Los Angeles: Powell Publishing Co., 1929, p. 352.
[2] *Ibid.,* p. 355.
[3] *Ibid.,* p. 353.
[4] William Heath Davis, *Sixty Years in California.* San Francisco: A. J. Leary, 1889, pp. 516-517.

Another popular boat was the *New World,* originally built for excursion trips on the Hudson River in New York. In 1849 the boat was about to be attached by a sheriff. Before proceedings could be started, the *New World* was off Cape Horn en route to the Sacramento-San Francisco run, which it once made in five hours and forty-six minutes.

River traffic continued its phenomenal growth until railroads were built and began competing and debris from hydraulic mines was washed down to choke the channels. In 1850 the Sacramento River fleet consisted of eighteen steamers, nineteen brigs, and twenty-one brigantines. By 1851 there was a semblance of organized traffic, with daily service of government mail from San Francisco. For the next ten years a number of steamship companies ran boats the year round on the San Francisco-Sacramento run.

While the city of Sacramento was the principal terminal, river traffic was carried on to Red Bluff, 246 miles north of San Francisco on the Sacramento, and to towns on the tributary Feather and Bear rivers. In 1849 regular sailings were advertised from Nicolaus, at the junction of the two latter streams. The Feather was at one time navigable through Marysville as far north as Oroville. Passage on the Bear River was possible to Johnson's Crossing. In a single day in 1851, seven steamers arrived in Marysville. Traffic grew to such an extent that the Court of Sessions ordered prosecution of persons causing congestion at the Marysville landing.

On the San Joaquin River, the shipping was about the same. Stockton, originally called Tuleberg, the principal port, became a city, albeit of tents, almost overnight. A New York *Tribune* reporter in 1849 described Stockton as "a canvas town of 1,000 inhabitants and a port with twenty-five vessels at anchor." [1] Another writer, in May of the same year, said: "Stockton that I had last seen graced by Joe Buzzel's log house with a tule roof, was now a vast linen city. The tall masts of barques, brigs and schooners were seen high pointed in the blue

[1] Bayard Taylor, *Eldorado, or Adventures in the Path of Empire.* New York: George P. Putnam & Co., 1857, p. 77.

vault above, while the merry *yo-ho!* of the sailor could be heard as box, bale and barrel were landed on the banks of the slough."[1]

Following the decline of gold mining, the large increase in settlers in the southern part of the Great Valley created a heavy, new demand on river transportation. Barges were put into service. In April, 1870, the steamer *Tulare,* towing a barge, took upstream 200 cords of redwood posts, 6,000 feet of lumber, and 160 tons of flour, sugar, bacon, and agricultural implements. The steamers and barges returned laden with wheat, sometimes carrying as many as 9,000 sacks, each averaging 120 pounds.

Railroad rates were still too high for farmers in 1893. In that year Fresno merchants were shipping goods down the San Joaquin River to Firebaugh in the *Empire City.* The largest steamer on the San Joaquin tributaries was the 400-ton *Centennial,* which carried 6,000 sacks of wheat to Hill's Ferry. Still the means of transportation were not adequate during the grain harvest. Once when the *Clara Crow,* with a large barge, landed at Crow's Landing to take on a load of grain, every grower insisted that his load be taken. Lack of space prevented such a course; so the captain auctioned off space for 300 tons, the successful bid being three dollars a ton.

During the height of the grain era, in the early 1880's, a barge was built 230 feet long, 40 feet wide, with a capacity of 18,000 sacks of wheat. It was navigable in 5 feet of water.

On the Merced River, steamers passed as far as Cox's Ferry and to the old Stevenson and Turner ranches, where they loaded wool and grain. Pioneer residents of Merced tell of seeing the smoke of steamers working against the current.

Inland navigation again will increase in importance. Even today the value of cargo borne by boats on the Sacramento and San Joaquin rivers runs into big figures. In 1934, shipments of 1,183,654 tons valued at more than $35,000,000 were carried on the Sacramento; 1,046,066 tons worth more than $38,000,000, on the San Joaquin.

[1] *An Illustrated History of San Joaquin County, California.* Chicago: Lewis Publishing Company, 1890, p. 67.

THE HYDRAULIC MINERS

The first comers to the rich sands of the river bars needed only a pan, a pick and shovel, a crowbar, and running water to mine the gold that glinted in the gravel of the clear streams. Later, a double-bottomed box, mounted on rockers like an old-fashioned cradle, was filled with the metal-heavy sands, and water separated the coarse rocks from the flaky gold. This was placer mining at its simplest. As the bars became exhausted, a long butcher knife was used to pick the metal from the gold veins in the near-by rocks.

Once the gold had been mined from the surface of the ground, it became necessary for the miners to go deeper for the precious metal. This was most easily obtained through the method known as hydraulic mining. At first the machine used was a rough affair of two sluice-board walls and a length of canvas sacking. Water flowing swiftly downhill was conducted through the device and directed against gold-bearing soil. As time went on, this apparatus was supplanted by more efficient equipment—lengths of iron pipe that sent powerful streams of water against the clay and gravel banks. Millions of dollars worth of crude gold was washed out in this way.

The water flowing through the gigantic nozzles of the hydraulic apparatus washed the banks of the rivers and streams farther and farther back from the bed. The lighter soils and gravels were gouged out and washed away.

But quartz gold still seamed the cliffs, and more powerful streams of water were used to shatter the rocks and boulders. The rivers became clouded with the dirt, and the water from the mines rushed on down the valley carrying a sterile load of silt and gravel that was unfit for any growing thing.

The farm lands became a wasteland of muck. Fruit trees began to wither, and grain died on the stalk. Farmhouses were buried halfway to their eaves in the muddy streams. Dirt, called "slickens" by the farmers, fouled the channels; and only launches traveled on the upper Sacramento where steamers once

had hauled freight and river passengers. The beds of the rivers, raised by the accumulated debris, could not hold the winter floods; and every year more and more "slickens" poured into fertile fields.

Finally, to fight the hydraulic miners, the valley men organized the Anti-Debris Association of the Sacramento Valley. Laws passed in 1893 forbade uncontrolled hydraulic mining, and the farm lands of the Sacramento were saved from the moving mountains.

Much damage had been done to the valley farms by the mining industry; but one contribution of lasting benefit is directly traceable to the farmers' one-time foe, the hydraulic miner. Ditches built in the fifties to conduct water to the mining sites became the bases of the early foothill irrigation systems that carried water to fields and orchards.

John Bidwell, leader of the first emigrant train overland to California in 1841, whose miles of farms grew from a fortune made in mining, in 1884 wrote: "Irrigation is the natural successor to hydraulic mining and important beyond all computation. By showing that waters can be conducted anywhere, hydraulic mining has unwittingly solved a most important feature in the problem of irrigation." [1]

THE ERA OF WHEAT

Even without water some men found a way for a time of making new fortunes on the broad plains of the valley. On lands once thought fit only for grazing, new thousands of acres of golden wheat were being raised for the world market. This was a crop that needed only as much water as the earth could hold briefly in the spring, before the moisture sank deeper to the underground wells or dried out on the surface.

With the coming of the railroad in 1870 even the barren acres west of the San Joaquin were planted with wheat. By 1889 California led the nation in wheat production. In the fol-

[1] Sacramento *Union*, July 19, 1884.

lowing year a wheat-grower named Lowell Alexander Richards was credited with the operation of the largest farming outfit in the world. His crew of men cut and threshed a continuous and unbroken field of standing grain clear across the valley, from the Sierra Nevada foothills east of Ripon to the Coast Range foothills west of Westley. In 1892 the Kings of Wheat were supreme, with less than one hundred men owning 1,600,000 acres of land in the Sacramento Valley. Wheat was a better source of wealth than gold, because once the gold was taken from the land it was gone, but wheat could be planted again in the spring.

But even the golden grain could not be taken from the soil forever. As early as 1892 the lands that had been planted to wheat slowly were being drained of the chemicals that all plants need for growth and were becoming poorer. That year the yield of wheat was one-third lower, and by 1906 large-scale wheat-growing was actually a losing venture. Large sections of the land were being abandoned as arid wastes.

Water was needed to reclaim them. Water would permit a number of crops to be raised in the same soil—crops that would restore some of the precious chemicals. Irrigation was the answer.

THE LAND GETS WATER

The Spaniards first introduced irrigation into the region now known as California a century and a half ago. The mission padres constructed rough ditches to carry water to the gardens and orchards they had planted in the wilderness.

During the years when cattle raising and the dry farming of wheat and barley held first place, irrigation developed slowly. It did not become a factor of central importance until the era of grain had passed its peak and farmers began turning their attention to growing fruit and vegetables by intensive cultivation of the soil.

The use of irrigation increased rapidly from that time on, until finally in 1934, in the Great Valley alone the irrigated area

amounted to 2,105,757 acres—6 per cent of the total irrigated area of the state. The California State Engineer has estimated that this huge expanse can be increased fourfold if irrigation is pushed as far as possible, and that a total of about 8,356,000 acres in the valley finally can be brought under irrigation.

Cattlemen pasturing their herds on the plains of San Joaquin Valley needed fresh green grass and water for their stock. They turned the high flood waters of winter into the great meadows through which the river flowed. The water drained off gradually as the flood level fell. Those fortunate enough to own land along the banks had ample grass for grazing purposes and hay, but cattlemen holding land above flood level found their fields left high and dry.

Bitter feuds over water developed among the cattlemen and between the cattlemen and farmers. For many years these feuds revolved around Henry Miller of Miller and Lux, largest landholder the state has ever known, who acquired between two and three million acres and is said to have been able to drive his herds on his own land from Oregon to the Mexican border.

Miller gained control of the land on both sides of the San Joaquin River for a distance of 120 miles by buying up cheaply great blocks of swampland in early days. He built levees along the banks so that he could direct the river water exclusively onto his own lands. When the terrible drought of 1862-64 burned up the grazing lands and cut down the number of cattle in the state from two million to less than a half million head, Henry Miller had hay to feed his cattle, and made enormous profits buying up the starving cattle of less fortunate ranchers and selling the carcasses for hides and tallow.[1] Miller also gained control of the area to the south where the Kern River overflowed into a series of great swamps. He built a canal 100 feet wide and 50 miles long to change the course of the river and divert the water to his own land. When hundreds of settlers who needed the water to grow their crops objected, he insisted that the water

[1] Edward F. Treadwell, *The Cattle King, a Dramatized Biography*. New York: The Macmillan Co., 1931, *passim*.

in any part of a river went with the ownership of the land along its banks. The war for water was carried into the courts and more than once broke out into armed struggle.

The right to use the water from any particular part of a river in California was fixed in early days by what is known as riparian law. The law, borrowed from England, held that the owners of all lands bordering streams had the right to the whole flow of the stream, "without interruption or alteration." This was suited to England, where rain comes regularly and plentifully and where there is no irrigation problem; but some experts believe it unsuited to the semiarid valleys of California, where every drop of water counts and where the value of farm land depends on the amount of water it can get. After years of disputes over water rights the California courts finally decided that the rights of the owners of river-bank or riparian lands should be limited justly to "reasonable use" of water.

Although some of the first irrigation projects were controlled by the railroads, which had received millions of acres of land from the federal government, or by the great landowners, in many cases the valley settlers themselves came together and planned the construction of ditches and canals. There are memorable tales of the heroic bands of men who worked day after day in the glaring sunlight, cutting mile after mile of ditches through the dry, hard earth with ordinary hand tools to bring life-giving water to the land. It was natural that these farmers should resent losing the results of their labor. Organized into settlers' associations, they played an important role in the early days of the long struggle for publicly owned district and state-wide irrigation projects.

The first irrigation canal in the San Joaquin Valley was built in 1851 by Edward Fitzgerald Beale on El Tejón Ranch. Another name important in the history of irrigation in the valley is that of Moses Church, who braved the anger of the cattlemen and organized the Fresno Canal and Irrigation Company for the purpose of constructing a canal-and-ditch system to carry water

CROPS—Typical products of the Central Valley's irrigated farms are grapes (above), cherries (right), and olives (below).

DROUGHT—A deserted fruit farm is mute evidence of what happens in the Sacramento Valley when the irrigation supply fails.

SALINITY—A salt marsh is the result when ocean water invades the delta lands.

from the San Joaquin River. The canal he built, known as the Church Ditch, carried water to meadows in the district in which Fresno is now located.

By the spring of 1872, two years after the Church Canal was built, the diversion of the river water to this point had made it possible for a farmer named A. Y. Easterby to cultivate 2,000 acres of wheat in the dry heart of the valley. This flourishing wheat field, the only green spot on the burnt, brown plains between Paradise Valley and El Tejón Pass, caught the attention of Leland Stanford and Mark Hopkins, who with a group of engineers were riding through to chart the course of the railroad they were planning to build across the valley. It so impressed them with the possibilities of the region that they decided to locate a terminal and town at that point—today known as Fresno.

The first really large irrigation project was the San Joaquin and Kings River Canal, constructed by a group of San Francisco financiers in 1871. This was hailed nationally as the greatest venture of its kind since the construction of the Erie Canal in the East. Within two years its effects began to show in an amazing increase in the grain harvest. News of this bumper crop and the resulting land boom reached Washington and aroused the interest of the government in the possibility of irrigation in California. Out of this interest grew California's state-wide plan for irrigation. Called the Alexander Plan, it was the ancestor of the Central Valley Project.

Already in those early years the danger of unlimited control of water by private individuals at various points along the rivers was clear to many ranchers. A growing demand developed for control of irrigation by the people of the state. In 1875 the Farmers' Grange, an organization which has done much to protect the interest of smaller ranchers, began agitation for the passage of an irrigation bill through the California Legislature. The bill was passed, creating the West Side Irrigation District. A board of commissioners appointed to investigate the water needs of the districts recommended the construction of a 190-

mile canal to Antioch, with a head gate at Tulare Lake and an outlet at Fuller's Point, to provide water for 505,717 acres. Plans called for this new canal to cut across the San Joaquin and Kings River Canal, which had been taken over by Miller and Lux. Miller and Lux obtained a writ which tied up the work for ten years.

Shortly after 1876 the Centerville and Kingsburg Irrigation and Ditch Company was organized. Its shares were sold to ranchers whose lands would be served by the water. The ranchers who bought shares were assigned certain portions of the work of excavation and construction. Time spent by these farmers on building the ditch was recorded, and in exchange the Kingsburg storekeeper gave the men credit for home or farm supplies. Both cattlemen and financiers made fun of these twenty-four pioneers. But they completed their job. In 1879 the men who had toiled in swirling, choking clouds of dust saw water in the ditches all the 35 miles between Centerville and Kingsburg.

In 1887, C. C. Wright, a Modesto lawyer, introduced a bill into the Legislature which was enacted into law on March 7 of that year. Known as the Wright Act, this was hailed as one of the greatest steps toward a unified development of the Great Valley. It provided that irrigation should be a public service. Since its passage some fifty active irrigation districts have been formed and more than six hundred dams built, including the Don Pedro Dam serving the Modesto and Turlock districts, Melones Dam serving the South San Joaquin and Oakdale districts, and Exchequer Dam serving the Merced district.

Fed by a network of irrigation canals, the valley bloomed. Over its broad acres spread a patchwork of green fields. New crops were grown—grapes, oranges and olives, sugar beets, rice—where only cattle and grain had been before.

But the valley's water problem was not yet solved. For the water supply was not yet enough to go around. Some lands had plenty of water, but others had to be abandoned because of dangerous aridity.

WATER–BUT NOT ENOUGH

During the years 1905 to 1911 interest in intensive farming grew very rapidly. Small farms of seven to ten acres were cultivated intensively, with great amounts of water being used. Banking syndicates pushed farming along these lines, and the whole pattern of California agriculture changed.

Soon the demand for water exceeded the normal surface flow, and ranchers had to find other sources. The result was intensive pumping from wells. This was the second stage of irrigation in California. From 1913 to 1929 the amount of land irrigated by ground water pumped from deep below the surface of the soil increased fivefold, and in 1929 wells supplied water to 28 per cent of the irrigated lands.

After a time, pumping cut down the water supply to such an extent that water levels lowered alarmingly and surface water was available only in very limited quantities. The expense of pumping water became so great that many of the smaller ranchers were forced into bankruptcy and lost their farms.

The power needed to raise a gallon of water, which weighs about 8 pounds, the height of one foot costs the rancher a certain amount of money. To raise the same gallon of water 100 feet costs not only 100 times as much, but the rancher must pay the increased expense of drilling additional wells and installing more powerful machinery. Thus it can be seen that a rancher can farm an acre of land at a profit only if he pumps water from a reasonable depth.

By 1933 pumping plants were almost as numerous as houses in the southern San Joaquin Valley. It soon became plain that the underground water deposits were being overdrawn. In the orange belt north of Lindsay wells that had struck water at from 35 to 120 feet in 1921 had to be dug as deep as 60 to 220 feet ten years later. In this section of the valley, where the original bedrock is closer to the surface, some of the wells drew salt water. By 1936 more than 20,000 acres of highly developed land had been abandoned because of the falling water level, and water was being overdrawn on more than 400,000 acres.

For years, far-seeing men had been fighting for conservation of the natural resources of the valley, for control of the invaluable water supply at its source, and for use of it in a manner that would benefit all of the people and give them the necessary safeguards for the future.

STATE-WIDE WATER PLAN

The attempt to develop a water plan that would operate for the valley as a whole—finally achieved in the Central Valley Project—began almost a century ago. In 1850 the very first session of the California Legislature that convened after the Constitutional Convention of 1849 passed a law that required the "Surveyor General to prepare plans for improvement of navigation, providing drainage, and furnishing irrigation water."

Two events helped to arouse interest in the question within the next few years. In 1860 it was discovered that the effects of hydraulic mining were hampering navigation on the Sacramento at the mouth of the American River, and the next year a heavy flood caused serious damage. The Legislature went no further at this period, however, than to pass a bill in 1866 providing for a survey for a canal to lead from the Sacramento River near Colusa to Cache Slough near Rio Vista.

During the administration of President Ulysses S. Grant, the construction of the San Joaquin and Kings River Canal drew the attention of Congress to the importance of irrigation in its new ocean-frontier state. In 1873 Congress asked the Secretary of War to investigate irrigation possibilities in the Sacramento, San Joaquin, and Tulare valleys.

The committee of three appointed by the Secretary of War to carry out the investigation made a report to Congress the next year. This report was known as the Alexander Plan, after Colonel B. S. Alexander of the Army Engineers Corps, who headed the committee. (The first professor of geography at the University of California, George Davidson, was also a member of the committee.) The plan, drawn up nearly seventy years ago when men knew much less about the make-up of the earth

and the habits of water than they do today, proposed the construction of a number of canals in almost exactly the same locations as the canals provided for in the present Central Valley Project. It outlined a detailed system of irrigation. In general, the Alexander Plan is correctly described as the "first comprehensive water plan for the Central Valley."[1]

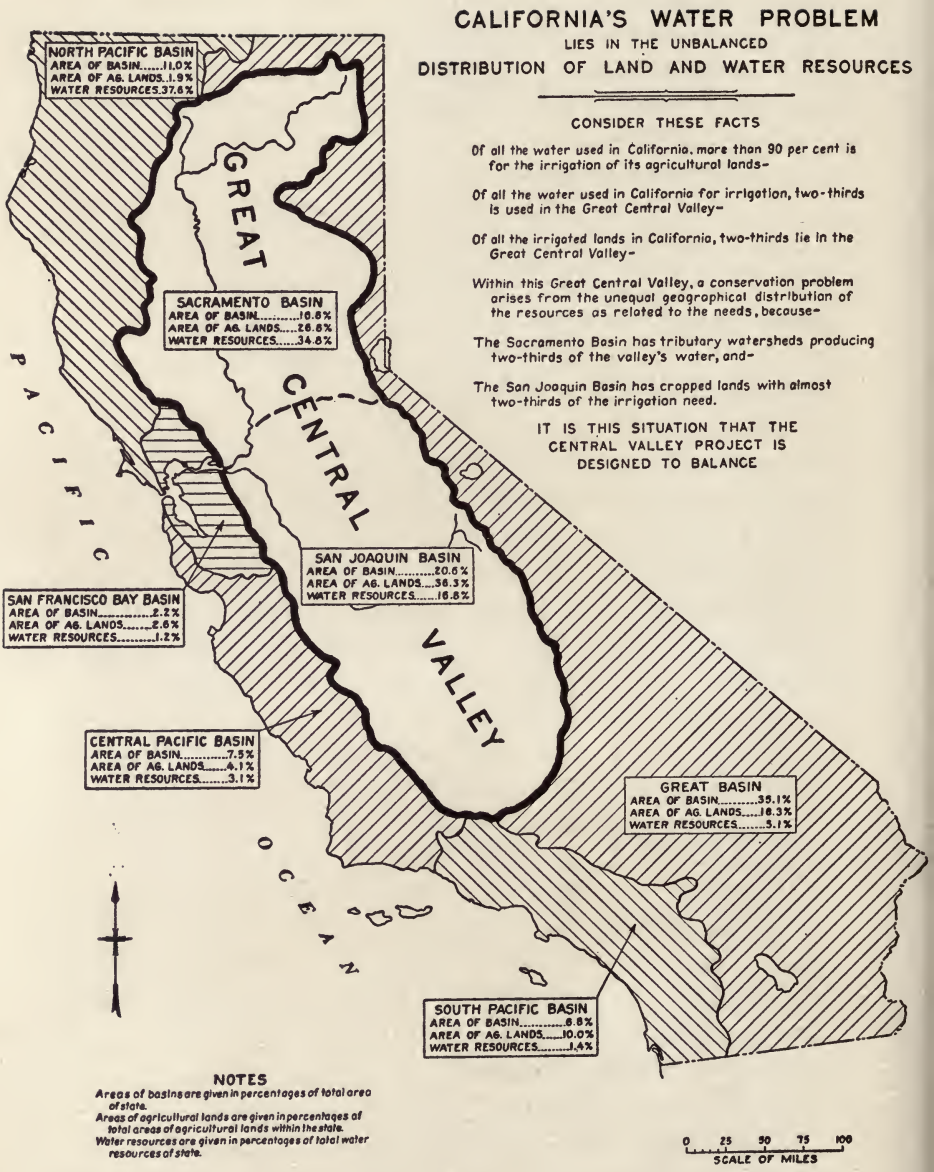
Colonel Alexander showed the great importance and urgency of California's water problem by picturing the situation in terms of the eastern states where people were used to having all the water they needed. He wrote: "The subject of irrigation is a novel one to the inhabitants of the states lying east of the 100th meridian where the harvests are so uniformly assured that a season of five or six weeks of continuous drought during the growing of crops would be looked upon as a national calamity and prayers doubtless would be offered in the churches for rain. In the East the yearly rainfall is somewhat regularly distributed through the different months; but on the Pacific coast there are two very marked seasons—one long, dry, and almost cloudless, embracing parts of the spring, all of the summer, and part of the autumn; the other season comparatively short and wet."[2]

Although the plan was a good one, it would have been impossible to carry it out at the time, even if enough money had been available, because in those days engineers had not yet made any detailed surveys of the region and its water resources. A series of studies launched in 1878 by California's first State Engineer, William Hammond Hall, was designed to unearth the necessary facts. But the Legislature failed to realize the vital importance of Hall's work and refused to provide the necessary funds. The work had to be dropped. For over forty years no other detailed survey was made. Meanwhile as time went on, the valley's dwindling water supply became an urgent problem demanding quick steps for its solution.

The whole question came before the citizens of the state again in 1919, when Robert Bradford Marshall, the Chief

[1] "History of the Central Valley Project." United States Department of the Interior, Bureau of Reclamation, Sacramento, July, 1940, p. 1 (mimeographed).

[2] Walker R. Young, "Preserving the Central Valley—A Brief Sketch of the Reclamation Bureau's Vast Project in California," *Civil Engineering*, IX (September, 1939), 543.


CALIFORNIA'S WATER PROBLEM
LIES IN THE UNBALANCED
DISTRIBUTION OF LAND AND WATER RESOURCES
CONSIDER THESE FACTS
Of all the water used in California, more than 90 per cent is for the irrigation of its agricultural lands-
Of all the water used in California for irrigation, two-thirds is used in the Great Central Valley-
Of all the irrigated lands in California, two-thirds lie in the Great Central Valley-
Within this Great Central Valley, a conservation problem arises from the unequal geographical distribution of the resources as related to the needs, because-
The Sacramento Basin has tributary watersheds producing two-thirds of the valley's water, and-
The San Joaquin Basin has cropped lands with almost two-thirds of the irrigation need.
IT IS THIS SITUATION THAT THE CENTRAL VALLEY PROJECT IS DESIGNED TO BALANCE
NORTH PACIFIC BASIN
AREA OF BASIN.....11.0%
AREA OF AG. LANDS..1.9%
WATER RESOURCES.37.6%
GREAT
CENTRAL
VALLEY
SACRAMENTO BASIN
AREA OF BASIN.....16.8%
AREA OF AG. LANDS.....26.8%
WATER RESOURCES.....34.8%
SAN JOAQUIN BASIN
AREA OF BASIN.....20.6%
AREA OF AG. LANDS....36.3%
WATER RESOURCES.....16.8%
SAN FRANCISCO BAY BASIN
AREA OF BASIN.....2.2%
AREA OF AG. LANDS.....2.6%
WATER RESOURCES.....1.2%
CENTRAL PACIFIC BASIN
AREA OF BASIN.....7.5%
AREA OF AG. LANDS.....4.1%
WATER RESOURCES.....3.1%
GREAT BASIN
AREA OF BASIN.....35.1%
AREA OF AG. LANDS.....16.3%
WATER RESOURCES.....5.1%
SOUTH PACIFIC BASIN
AREA OF BASIN.....8.8%
AREA OF AG. LANDS.....10.0%
WATER RESOURCES.....1.4%
PACIFIC
OCEAN
NOTES
Areas of basins are given in percentages of total area of state.
Areas of agricultural lands are given in percentages of total areas of agricultural lands within the state.
Water resources are given in percentages of total water resources of state.
0 25 50 75 100
SCALE OF MILES

Hydrographer of the Geological Survey, realizing the increasing dangers of the situation from his studies of the valley's water supply, took matters in his own hands. He sent a plan to the governor, writing him "in a personal capacity."[1] His recommendations, known as the Marshall Plan, included a scheme for "transferring surplus waters from the northerly to the southerly portion of the Central Valley."[2] Such a plan looked like an impossible dream at the time—and yet it is exactly what is being accomplished by the Central Valley Project today. The Marshall Plan also proposed the construction of a number of storage reservoirs on the main rivers and "a system of canals skirting the entire rim of the Sacramento and San Joaquin Rivers."[3]

People in California became interested again. In 1921 the Legislature finally appropriated $200,000 for a broad study of water resources. It directed the State Engineer "to determine a comprehensive plan for the accomplishment of the maximum conservation, control, storage, distribution and application of all waters of the State, and to estimate the cost of constructing dams, canals, reservoirs and other works necessary in carrying out this plan."[4]

The State Engineer submitted a complete report to the Legislature in 1923. From that time on the Legislature kept passing additional appropriations—amounting to over a million dollars in all—for further work on plans and surveys. The fourth and final plan, drawn up by State Engineer Edward Hyatt after ten years of investigation, was adopted in 1931 with a few minor changes. This was a state-wide plan for water conservation proposing smaller projects for the control of southern California streams as well as the Central Valley Project for the great interior valleys.

[1] Walker R. Young, *op cit.*, 543.
[2] *Ibid.*
[3] *Ibid.*
[4] *Ibid.*

Part II

HOW THE PROJECT WAS BUILT

MONEY, MEN, MACHINES, MATERIALS

We have seen that for nearly a hundred years men studied ways to solve the immense problem of California's water shortage. Hydraulic engineers measured the rivers. Surveyors charted the hills. Topographers mapped thousands of square miles. Plan after plan was drawn up, picturing how to harness and direct the water resources of the State.

These plans were not wasted. The best part of each was used to make up the great state-wide water plan, from which the Central Valley Project was derived.

The master plan as formulated by State Engineer Edward Hyatt and the Division of Water Resources of the Department of Public Works was submitted to the California Legislature for consideration in 1931. Many interested persons urged that the part of the master plan known as the Central Valley Project should be approved at once and money provided so that this long-needed work could begin. They considered this project to be the nucleus or minimum part of the master plan urgently required for immediate development.

After long delay due to opposition to the plan from those who claimed it would increase taxes or provide government competition to private power companies, the project was approved by the Legislature; and on August 5, 1933, the Governor signed the bill giving the state authority to begin work.

The opponents did not give up, but at a special state-wide election held on December 19, 1933, the people of California voted their approval of the water-saving Central Valley Project.

Money

There was still an obstacle. Lack of Money!

One hundred and seventy million dollars was needed—and it couldn't be found. The state of California tried to sell bonds to secure the money. But 1933 was not a good year, the depression was serious, and it was hard to persuade people to buy these

bonds. $170,000,000! What a huge sum of money! Yet, if the cost were spread among all the people of California, the 6,062,000 residents would have to pay only $28.04 each. And when the benefits were considered—the lives and property that might be saved from future floods, the riches that would be added to the state each year—$170,000,000 was really a small sum for such an investment. The floods of 1937 and 1938 alone did $150,000,000 worth of damage in California, nearly enough to cover the entire amount required.

In 1934, no money!

In 1935, no money!

Finally it became clear that unless the United States Congress made funds available the whole idea would never get beyond the planning stage.

In 1935 the War Department recommended the construction of Shasta Dam, a part of the Central Valley Project, on the grounds that it would improve navigation on the Sacramento River and aid in controlling floods. Congress acted on the recommendation and authorized the expenditure of $12,000,000. An appropriation bill was passed that specified that the work was to be done by the Bureau of Reclamation of the Department of the Interior, which already had made some engineering studies of the Central Valley Project.

Why did Congress select the Bureau of Reclamation?

Because it is the greatest body of dam builders and irrigation experts in the world. Since it was organized in 1902, this Bureau has built 161 dams (including the monsters Boulder Dam and Grand Coulee) and more than 20,000 miles of canals and has reclaimed nearly 4,000,000 acres of arid lands in sixteen western desert states. The projects that it has built produce billions of kilowatt-hours of electrical energy annually, enough to supply all the power needs of a dozen great cities. Since the first reclamation project began operating in 1906, farms served by these works have produced additional crops to the value of $2,657,000,000—many times the cost of the project. The Bureau of Reclamation has accomplished great things by saving

farmers in many states from the menace of drought that in past years has driven hundreds of thousands of families from their homes.

On December 2, 1935, the United States Bureau of Reclamation officially took over the Central Valley Project, promising to make a good job of it, to begin and complete it in the shortest possible time with the funds to be provided year by year by Congress. The Bureau immediately began checking plans and estimated cost, making more studies of its own, and designing the dams and canals. Because of some necessary changes, and because of increased cost for labor and materials, it was found that a somewhat larger sum of money than the original estimate was needed, that the project would cost $228,010,000. Even at this price, all agreed that the Central Valley Project was still a bargain.

If this great sum of money were changed into pennies, and they were piled high, they would make a pile towering 215 miles above the earth; or if they were laid edge to edge, they would reach from San Francisco to New York. Big money? Yes! Yet this is just the value of the California orange and vegetable crop for one year.

After bids were made on certain sections of the Central Valley Project, a contract was let on July 6, 1938, for furnishing labor for the building of Shasta Dam to a great combine of twelve contracting companies, since no single contracting company was large enough to handle the job. This contract, in the amount of $35,939,450, was the second largest labor contract ever awarded on a federal irrigation project. The contractor posted bonds in the amount of $9,500,000 to assure his completion of the work.

Bids were called for the construction of Friant Dam, and on October 9, 1939, a contract was let in the amount of $8,715,-358.50 for furnishing labor only. This contractor posted bonds in the amount of $4,500,000.

The money invested in the project is not lost to the federal government. Through the sale of water and power the whole amount is expected to be returned within forty years to the

United States Treasury. And after that the project may stand for generations, continuing to add to the wealth of California and the nation.

The Builders

In 1936, when the newspapers carried many stories of the beginning of the Central Valley Project, thousands of men began moving toward Redding and Fresno to seek work on the two main units of the project that were to be constructed. They were attracted to this big job as steel is attracted to a magnet. But they came too soon; there was no work for them. They drifted away.

Two years later when large-scale construction was actually under way the project employed 5,000 men—5,000 pitting their strength and skill against the mighty forces of mountain, rock, and river.

Who are these men? What do they do?

They are men of many races and creeds, white men and black, thousands of men with strong arms, precise eyes, and alert minds, skilled in many trades, gathered here to put across the biggest job in California history. Here are workers of ninety-two different occupations and a dozen different kinds of engineers, all working directly on construction. Behind them are thousands more in mines and mills and factories throughout the land preparing the necessary steel, machinery, and equipment. For every man on the job there are two elsewhere getting material ready for the undertaking.

In the years of building up the West there has grown up a set of brave and hardy men who know the make-up of the earth. These are the construction workers and tunnel miners, the men who forced mile-long tunnels through the Rockies, built dams to store water, scored the surface of desert-dry but fertile areas with canals, stretched huge bridges over rivers, bays, and mountain gorges. On the job they spend months at a time in rough construction camps far out in wild mountain or desert country working hard and dangerously on mighty projects.

When one job is finished they move on to the next—from the six-mile Moffat Tunnel in Colorado to a flood-control dam in San Gabriel Canyon in southern California, from Boulder Dam to Bonneville. The families of many of these men move with them over the great spaces of the West.

The men building the Central Valley Project operate jackhammers, air compressors, concrete mixers, cranes, crushers, dinkeys, derricks, and draglines. They run graders, grout machines, hoists, power shovels, wagon drills, and water-clarifiers. They are blacksmiths, bricklayers, carpenters, electricians, firemen, laborers, locomotive engineers, machinists, and mechanics. They are miners, ironworkers, painters, pile drivers, plasterers, and plumbers. They are riggers and riveters, sheet-metal workers and steamfitters, welders and burners. They drive tractors and dumping trucks and flat beds and transit-mix trucks.

There are "powder monkeys," "muckers," "high-scalers," and "sand hogs." There are a "diver" and his tender, a "bootman" and a "nipper"; there are tenders for the endless belt conveyor that travels 168 miles a day.

Then there are the even more highly skilled workers: the scientists and the various kinds of engineers and other technical men. They have spent many years in colleges and technical institutes, learning what water is, where it comes from, what it does, where it goes, and how to control it. They can measure the snow and gauge the streams and calculate how much electric power will be delivered by the powerhouses under construction as a part of the project ten years from now and a thousand miles from its source; they can build a dam on paper and calculate how strong it must be to hold back a million acre-feet of water; they know how to examine a sample of rock taken from 200 feet below the earth's surface and from this determine the "strength" of the earth and its ability to support a 12,000,000-ton dam. There are hydraulic, civil, construction, electrical, and mechanical engineers working on the project as well as geologists, hydrologists, topographers, architects, chemists.

At the headquarters of the Bureau of Reclamation are other men who make very important contributions to the work. Long before actual construction could begin these men had to make drawings—blueprints—of each intricate detail of the huge project. The broad problems of water in the Central Valley were solved in 15,000 detailed drawings, about enough drawings to paper the walls of two hundred rooms. Engineers have a saying: "When the plans are done the job is half done."

The man credited with perhaps the greatest engineering skill in dam-designing is J. L. Savage, Chief Designing Engineer of the Bureau of Reclamation. He has been with the bureau for twenty-nine years, has been called to many far-off countries, including Puerto Rico, Santa Domingo, Panama, England, and Australia, for advice on engineering problems, and is considered the world's foremost authority on dam-engineering. He works under S. O. Harper, Chief Engineer of the Bureau of Reclamation at its western headquarters in Denver, Colorado. Commissioner John C. Page heads the Bureau in Washington, D. C., working under Secretary of the Interior Harold L. Ickes.

The boss "on the job" for the first five years of work was Walker R. Young, the Bureau's Supervising Engineer, with headquarters in Sacramento. In 1935 when he was transferred to California to take charge of building the Central Valley Project, he was Construction Engineer of Boulder Dam. In 1940 he was appointed Assistant Chief Engineer of the Bureau of Reclamation, moving to the Denver office, and R. S. Calland became Acting Supervising Engineer of the Central Valley Project. In direct supervision of the construction work being done by the various contractors on the three divisions of the project are three Construction Engineers—Ralph Lowry at Shasta Dam, R. B. Williams for the Friant Division, and Oscar G. Boden for the Delta Division.

At Camp Baird near Redding are four hundred boys of the Civilian Conservation Corps assigned to the Central Valley Project. Their principal work has consisted of cutting the trees

THE BUILDERS—Mechanic tightening grout pipes (upper left). Jackhammer operator drilling into rocky cliff (upper right). Bureau of Reclamation surveyor (lower left). Cableway signalman guiding a load by short-wave radio (lower right).

GOVERNMENT CAMP—Engineers, other government employees, and their families live in the neat town of Toyon in order to be near the Project.

TOYON SCHOOL—There are six classrooms in this school, which was built especially for the children of Shasta Dam workers.

DOOMED—Destined to a watery grave are the ghost mining town of Kennett (upper view) and the abandoned copper smelters (lower view) in the Shasta Reservoir area.

MACHINERY—An electric scoop shovel under Shasta cableways (upper left). Visitors ride skip across canyon (upper right). A big truck dumps a load of dirt (lower left). Cobble-size gravel on the 10-mile long conveyor belt (lower right).

and burning the underbrush from the 30,000-acre site of the Shasta Reservoir.

How much work can a man do? This is a question that must be answered as exactly as possible before plans are drawn up for any important undertaking. Knowing how much work a man can do makes it possible to work out in advance what are called labor costs, or the amounts of money in any construction or manufacturing job that must be paid out in wages. Finding the answer to this question comes under the heading of industrial engineering.

Let us see how an industrial engineer would go about answering this question. He would ask, what kind of tools will a man use? What kind of work will he do? What are the conditions under which he will work? What are the special dangers and difficulties he will meet on the job? Is he strong, weak, well, sick? What experience has he had? Has this sort of work been done before and if so under what conditions?

By answering these questions the industrial engineer is able to reckon the amount of work a man can do in one hour under given working conditions. This unit is called a man-hour. The usual method of determining a man-hour is to make a time study. An engineer goes to a plant or construction job and studies the men at work, using a stop watch to check the amount of time each man requires to do a certain amount of work.

The problem of determining the amount of work a man can do is a difficult one. To solve the problem one of the most important things to find out is what sort of tools a man uses, whether they are old-type tools or modern ones, in good condition or bad.

A tool is really like an extra hand grafted onto a man's body.

Perhaps now we understand enough about the question to see what engineers mean when they tell us that 80,000,000 man-hours of direct labor—probably an additional 160,000,000 man-hours indirectly—will be needed to build the Central Valley Project: enough man-hours to build a city about as large as Oakland with a 300,000 population.

Of course, we know that one man could not build the Central Valley Project even if he had a hundred thousand years to do it. But if one man *could* operate all the complex tools and do all of the work himself, it would take him 38,500 years to carry through the job, working eight hours a day, five days a week.

How many hours do the men building the Central Valley Project actually work?

Construction goes on continuously, twenty-four hours a day and seven days a week, but naturally each man does not work continuously. The work is carried on in shifts—that is, on a typical job, one group of men works from 8 a.m. to 4 p.m.; the "swing" shift goes on at 4 p.m. and works to midnight; the "graveyard" or night shift works from midnight to 8 a.m. In this way part of the men work while part sleep and the rest are free for recreation. Under federal regulations, the maximum hours that each man may work are set at forty a week.

Homes for the Workers

Where do the project builders live? Many of the workers have made their homes in communities already established, increasing the population of Redding, Fresno, Madera, Friant, Clovis, Antioch, Pittsburg, and other places near the centers of construction. But the site of Shasta Dam in a remote canyon about 5 miles from the nearest highway made necessary the building of additional near-by towns to house some of the workers. One of the first towns built was Toyon, named for the Indian toyon, or redberry, which grows in abundance there. Toyon is 3 miles from the dam site and was built by the government to house Bureau of Reclamation employees and their families. It consists of two large dormitories for single men, one hundred family residences, a park and recreation center, an office, a fire station, laboratories, a garage, and other buildings for community use. The population of this model town is 464. A similar but smaller Bureau of Reclamation camp was built near Friant Dam; its population is about 250.

Other towns have sprung up in the vicinity of Shasta Dam: Shasta Dam, built by the general contractor just below the dam

site, population 659; Central Valley, better known as Boomtown, population 1,771; Project City, population 565; Summit City, population 484. In these towns most of the contractors' employees live.

Toyon has no commercial establishments, but in the other mushroom communities are stores, service stations, a roller-skating rink, and motion-picture theaters. Toyon's public school is attended by 344 children of the builders of Shasta Dam. This school serves Toyon and one other settlement. In this recent wilderness a school bus picks up children and takes them safely to and from classes. These boys and girls long will remember a part of their education—living here and watching the day-to-day progress in the building of the second largest dam in the world.

Mechanical Helpers

Some of the larger and more important machines used to build the Central Valley Project are the wagon drill, the air compressor, the dragline, and the belt conveyor; the mix plant, the air pump, the cableway, and the towers; the hammerhead and the whirley crane; the trimming machine and the concrete liner. In addition to these mechanical mastodons, there are thousands of other complex and simple tools: acetylene torches and X-ray machines; compass saws and ordinary screwdrivers—all the varied tools that have enabled man to add to his strength and to increase his reach and ability.

Early tools were very rough and primitive, but they did make it possible for man to change and improve his surroundings. The first shovel was probably only a flat stone fastened to a branch of a tree by a leather thong, but it enabled man to change the earth. Because of this change in the course of time he began eating different foods, he came to depend less completely on fishing and hunting, and his habits changed in other ways as well. He no longer had to go from place to place following his food. He began to settle down in one place and dig up the earth and grow his food. Then a pointed stick came into use as a plow, and he could raise better crops. Many generations

went by, and man captured the wild, shaggy horse of that distant day and tamed it to serve his needs. This marked a tremendous step forward in human development. The horse added to man's slight strength and helped him to increase his mastery of nature. A horse plus a pointed-stick plough made him a much better farmer; a horse plus a bent-log sled permitted him to move large objects over the earth.

In the course of centuries the plough was given a metal ploughshare; the pointed stick became a pick; the wheel was given handles and a body, becoming a wheelbarrow; two wheels and an axle became a chariot; four wheels and a body became a horse-drawn wagon. The shovel, now made of metal, remained much the same in shape as its stone predecessor. Then a larger shovel with two handles, drawn by horses, became the scraper.

When this century began, men still were working with these same simple tools—the shovel, the pick, the wheelbarrow, the scraper, and the wagon—to change the earth. But in the years following the turn of the century man's genius showed itself in new ways. Confronted with bigger problems demanding much greater skill and more powerful equipment than ever required before in their work, men developed the machines they needed at a tremendous rate. From 1900 to 1930 more improvements and advances took place in construction engineering than in the previous ten thousand years.

When construction work on the Central Valley Project commenced, the men and machines were ready; and both engineers and workmen were equipped with the experience gained at Boulder Dam and similar projects.

Drill, Scraper, and Scoop Shovel

Machinery was first used in exploring the dam site. Diamond and calyx drills began grinding down into the earth looking for the faults and flaws in the earth's surface.

Then came the machinery of excavation. Over the 400-mile length of the project, huge scrapers called "carry-alls" began scooping the "overburden" from the two dam sites at

Shasta and Friant and moving the earth for the canals. Drawn by tractors, each with the strength of twenty elephants, these lumbering carriers move away to the waste piles or embankments to dump their loads and without stopping to return for more. Giant electric scoop shovels with pronged teeth bite up tons of boulders, loose rock, and dirt and set them down in the oversize trucks—six tons to a bite. Each truck can hold 30 tons or five times the capacity of one scoop shovel. In the "good old days" the most a hand shovel could lift was about 10 pounds of dirt, and a wheelbarrow could handle only about 200 pounds. That means that a man using a hand shovel would have to dig down into the soil about 1,200 times to remove the amount dug out at one scoop by a power shovel. It means that 300 wheelbarrows equal one truck. This is progress.

Many of these efficient scoop, or "dipper," shovels are used on the project, varying in size and type, some electric and some powered by Diesel engines or gasoline motors. There are hundreds of trucks of many sizes and shapes, and probably most of them will be worn out before the job is finished. There are bulldozers, charging in with caterpillar treads and broad blades to push the earth before them; cowdozers with concave blades that pull the earth behind them; caterpillar tractors, called "cats," compactly powerful; and sheepsfoot rollers, leaving their thousand footprints behind them as they pack solid the earth of the embankment and fill.

When several million tons of earth, boulders, and loose, weathered rock had been removed from the Shasta and Friant dam sites, the builders encountered different rock—harder and more massive—rock not quite solid enough to serve as a foundation for a dam, but too tough to be dug out by power shovels. So "hard-rock" men, as they are called, advanced on the barrier with their whirling steel bits, their jackhammers and dynamite.

Wagon drills, the most modern machines yet developed in the battle with hard rock, were brought in. The largest number of these wagon drills ever used on dam construction whirred and cut their way into the rock, day and night, drilling dynamite

holes. Mounted on two pneumatic-tired wheels, they look much like small automobile trailers and are moved from place to place just as easily. Each drill is highly adjustable and can be set to drill at any angle or direction—overhead or underfoot—"top holes," breast-high, or "snake holes."

The idea of the wagon drill is very simple. It really serves as steel arms, holding and guiding the pneumatic drill as it bounds and twists and cuts its way into the foundation rock. Before the general use of wagon drills on jobs of this type, hand-operated rock drills or jackhammers were used to bore into the rock. The drillers were compelled to use smaller bits and were unable to drill so deep or to hold the drill so steady. Men operating these jackhammers developed great muscles but still they tired from the work. Today on the project, to a large extent, steel and springs take the place of bone and muscle. By the use of wagon drills 200 feet of tapered holes can be drilled in a single shift. About 20 feet a day was the most a man could make with the earlier types of drills.

In one month at Shasta wagon drills sank 60 miles of blasting holes. Each drill bores, on the average, one-half foot per minute. In the rock encountered at Shasta it was necessary to change the steel bit after each foot or so of drilling and to take it out for resharpening. The steel bits range in length from 4 to 12 feet when new. They are hardened steel rods with two or more sharpened cutting edges at their ends. The sharp end spins around, cutting through the rock.

How are these wagon drills operated? What is their source of power? Air! Air pressure!

Air Compressor

How is this air compressed? Part of the contractor's plant at Shasta dam site is a building housing big compressor machines, operated by electric motors, that gulp in air, ordinary air, at the rate of 84,000 cubic feet a minute and compress it nearly eight times. An air compressor works on the same principle as a bicycle pump, but instead of compressing air within a tire it presses it into a small space within a container strong enough to

hold it. From this container it is directed through pipes and air hoses to the drills (in all parts of the dam site), where it is released, passing over wheels with several blades. Thus the air turns the wheel and drill as it seeks an outlet to expand to normal pressure.

Everyone is familiar with the force of the air which makes an explosive noise when a tire is punctured, and yet automobile tires today seldom carry more than 35 pounds pressure per square inch. The air compressors at Shasta and Friant dams maintain a constant pressure of 110 pounds.

During the construction of the Central Valley Project the air compressors will "inhale" thousands of cubic miles of air, put it to work, and then release it. This is typical of the way that man makes the forces of nature serve him in this great job of construction.

When the excavating machines that remove the earth and rock from the tunnels, canals, bridge foundations, and dam sites have finished their task, the machines that move in the materials for construction are put to work.

Dragline and Conveyor Belt

One of the first machines encountered in making ready for construction is the gigantic walking dragline at the gravel beds. This machine waddles along like a huge goose with the 100-foot boom serving as the neck and the enormous bucket as the head. This mechanical pet that stands 10 stories high in its walking "shoes," when erect, reaches out and scrapes up 11 tons of gravel, placing it in the vibrator hopper. Fuel oil feeds its Diesel engine. A steel drum whirls about, winding the cablelike wire thread on a spool, pulling it over a wheel at the boom's end, and thus lifting the bucket with its 22,000-pound load. At the Shasta gravel or aggregate deposit, this tremendous dragline has a smaller, a brother dragline, helping to the limit of its six-ton capacity. These draglines are called "cherry-pickers" by the men because they are sometimes used to pick up boulders—"cherries"—too heavy for the men to lift or place on the trucks.

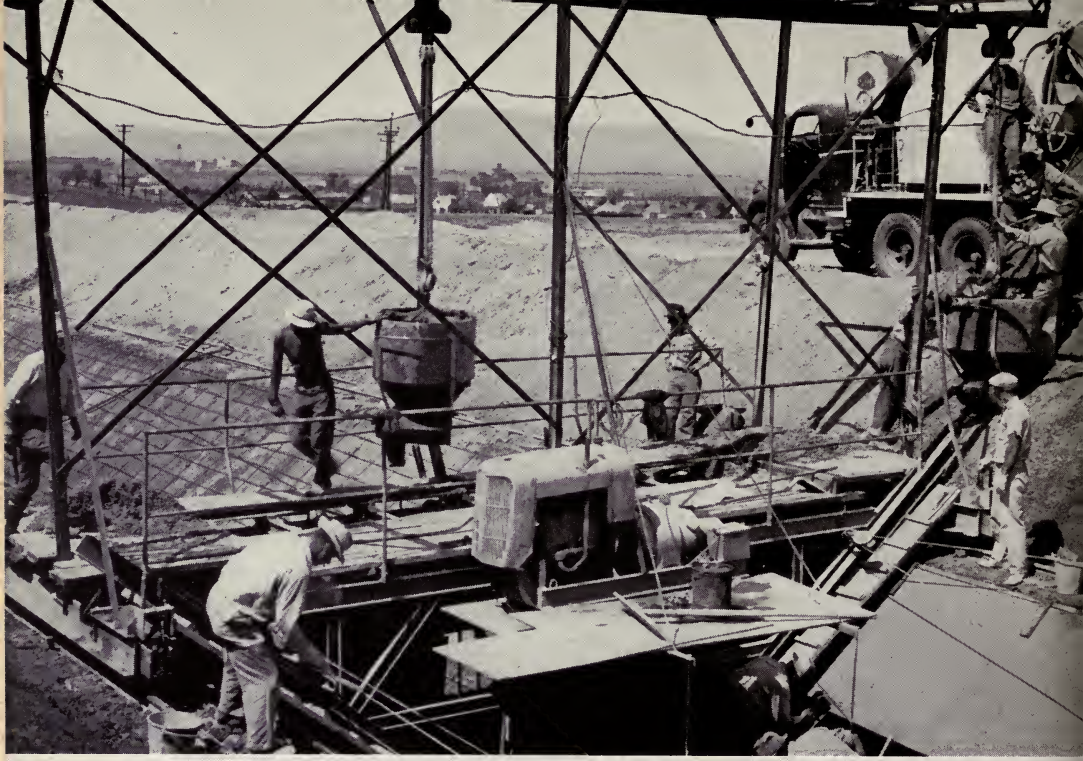
TRESTLE AND CRANES—Friant Dam is being built by th
trestle method. Buckets of concrete brought out on the stee
trestle are lowered into place by the giant hammerhead crane

In the preparation of aggregates, the sand and gravel needed for the millions of tons of concrete, there are other machines, important although not so spectacular. There is a moving belt which carries aggregates to the washing and screening plant, where oversize rock is put through a "jaw crusher." Here are a scrubbing trommel, where each stone and pebble is given a thorough washing; a cone crusher for special crushing; a "slugmill" for grinding and elimination; "hydroseparators," which whirl off dirt and silt from the sand; a "rod mill" to manufacture sand from fine gravel; a "rake classifier" for sorting; and many screens.

And then there is the most exciting machine of all, the 10-mile-long belt conveyor, the longest in the world, which carries the scrubbed and classified aggregates to the concrete-mixing plant near their final resting place in Shasta Dam. A conveyor belt is an endless belt similar to an escalator in a department store; but it is used for moving materials from place to place rather than for transporting people from floor to floor in a building.

Up and over the hills and down and across the canyons it moves, creeping slowly 6¼ miles an hour, looking from a distance like a tremendous caterpillar moving over the earth. At many places it seems to hug the ground; at one place it spans a chasm 90 feet above ground. Those obstacles that cannot be removed are bridged; in each trip of this hard-working conveyor it crosses the Sacramento River twice, leaps four creeks, five county roads, the state highway, and the main line of the railroad.

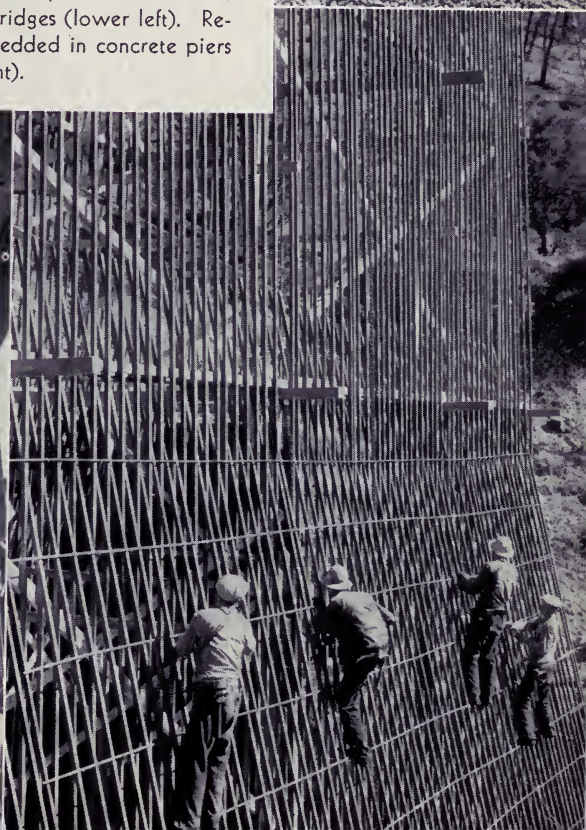
Slowly, doing the work of a thousand motor trucks or a hundred railway cars, it rolls along with hundreds of tons on its back, delivering this amount each hour, starting at an elevation of 490 feet at Redding and crossing a pass 1,450 feet above sea level near the dam site. Aglow at night with scattered lights, the unbroken stream of aggregates flows over the hills, night and day, month after month. The stream will keep on flowing, if present plans are carried through, until the four years required to move 10,000,000 tons have passed.



CANAL BUILDER—A paving machine lays a 3-inch lining of concrete on the sides and bottom of the excavated ditch.

WATER CARRIER—A completed section of the Contra Costa Canal. The other project canals will be somewhat larger.

MATERIALS—Cement is stored in these tall silos (upper left). Gravel is stored in great bins (upper right). Heavy structural steel is used in towers and bridges (lower left). Reinforcing steel is embedded in concrete piers and walls (lower right).



SHASTA DAM—The dam site before the work was started (upper). How it will look when completed (lower).

To build this conveyor was a big job in itself, although in contrast with the project it was a relatively unimportant preconstruction detail. Beginning at the sand and gravel deposits near Redding, a 100-foot right of way had to be surveyed, secured, and cleared and some embankments cut on the 10-mile route to the construction site. Then the framework of steel and wood had to be built to hold the 16,000 rollers on which the 20 miles of rubber belting move. The belts used on the conveyor are 36 inches wide. More than 500,000 pounds of cotton and nearly 1,000,000 pounds of rubber went into their manufacture —enough cotton and rubber to make nearly 700 automobile tires.

What keeps the sand and gravel on the conveyor? The sides of the belts are held up by the two outside rollers, which are set in the frame at an angle, thus forming a trough.

The conveyor is made up of forty sections, or "flights," with varying lengths of belts, depending on the contour of the hills. The first twenty-two sections are powered by 200-horsepower motors; the next four sections, going downgrade as much as 25 per cent to the Sacramento River, require no power—in fact, the weight of the load in motion, called kinetic energy, is used to generate electricity which helps pull the other sections up the steep hills. The last fourteen sections, climbing from the river to the stock piles and to the mix plant, also require 200-horsepower motors to move each flight.

Along the route of the conveyor are many telephone stations for emergency use. An intricate system of automatic electric controls can stop the entire conveyor if a section gets out of order. The location of the breakdown is indicated on the central control panel.

Along the route are many signs reading "KEEP OFF—BELT STARTS WITHOUT WARNING—DANGER," and at each transfer point are crossbars to prevent anyone from riding the belt.

When the load reaches the end of each flight, it is dumped through a steel chute to the next section, continuing its chute-the-chute ride to its destination, the concrete mix plant.

Cement Pump and Mix Plant

The machine for moving six million barrels of cement from railroad cars to the ten storage "silos" near the dam site is strange at first sight although it is common in the cement industry.

The cement is not moved by truck, train, or belt; it is blown from the boxcars to the cement "silos," which are tall storage tanks. Here again we see compressed air put to work for man.

When the boxcars, containing more than 120,000 pounds of bulk cement, are "spotted" on the siding, the door seals are broken and an electric-powered portable air pump is placed in the car. The air pump, mounted on two rubber-tired wheels, is called the "Chinese dragon" by the workmen because it has a huge "head" which eats its way through the bulk cement and a long rubber hose "tail" which carries the cement out of the car. The pump is operated by remote control by means of push buttons. When the operator presses the switch a disk begins whirling about near the floor, gathering the cement and feeding it into the pipe opening. Within this pipe an 8-inch screw spins about at 500 revolutions per minute, forcing the cement into the air ring. Here in the air ring the finely powdered cement is lifted and begins its long, floating journey to the silos. Air, entering the "line" through injection points in the ring, aerates and gives buoyancy to the cement. Air pressure of about 40 pounds per square inch then forces the suspended particles out of the hose to the silos, each of which holds twenty-two carloads of cement. In the same way a stationary cement pump blows cement from the silos more than a mile to the concrete-mixing plants.

The mixing plant at Shasta is interesting for two reasons—its size and the scientific exactness of each batch. Nearly everyone is familiar with the simple process of mixing concrete: the blending of cement, sand, gravel, and water. But here, where the concrete must be solid and free from flaws to hold the great weight of waters, the amount of each ingredient automatically is weighed and recorded in the batching plant before the five units begin rolling with their eight tons of mix.

Each unit of the mixer holds an average batch of 14,782 pounds of aggregates, 1,540 pounds of cement, and 900 pounds of water, which is fed to it by hopper and hose. When filled, the drum begins rotating, and after turning over an average number of thirty times, the mix is ready. The wet concrete is then dumped into cars on a most unusual elevated endless railway, called so because of its circular track. The cars, holding 32 tons of cement, move around to the loading dock, dump their load, and return on the steel circle to the hopper. The diameter of this circle is 420 feet. This endless electric railway making a trip of a quarter-mile is no doubt one of the shortest in the world, and the engineers who operate each of the electric engines make this merry-go-round ride hundreds of times a day.

Cableway

The last and most important machine used in the placement of concrete at Shasta is the "radial" cableway system, with its structural steel head tower 460 feet, or more than forty stories, above ground and its anchorage 102 feet, or more than eight stories, below ground. This tremendous steel pyramid is 562 feet taller than the Los Angeles City Hall. The three upper "floors" of the tower are the operators' rooms, machinery room, and rigger's cable room, reached by an elevator which creeps up the outside of the structure.

From this great head tower seven cableways stretch or radiate, to smaller, movable "tail" towers affectionately called "Twelve-toed Petes." These young giants, each supporting up to a half-mile of steel cable, received their odd name because they have twelve wheels on each leg that, strangely enough, do resemble a dozen toes. Each tower holds a weight of more than 100,000 pounds.

The head tower is centrally located on the west side of the Sacramento River. Three of the "tail" towers are spaced on tracks at the top of the east abutment, a half-mile away; two more, below the dam on the east side; another, below the dam on the west side; and another, at the top of the west abutment.

To each, powerful steel cables stretch fanwise over the gaping dam site. The direction in which each cable reaches out from the head tower is changed whenever necessary by moving the "tail" tower along its curved track. It is on these 3-inch steel cables that the mix takes its last ride. When the endless railway empties its burden into the huge buckets, each holding 16 tons of wet concrete, these buckets are picked up, swung out and over the excavation on the great cableway, then lowered—down, down—and dumped of their load into the final resting place.

Trestle and Cranes

The method of placing concrete at Friant Dam and at other parts of the project varies according to the size and kind of work to be done. At Friant a steel trestle nearly a half-mile in length and 200 feet high performs service similar to the cableways at Shasta. This trestle—whose legs will become part of the dam by being swallowed up as the concrete rises higher and higher—has single railroad rails laid along each outer edge 44 feet apart. Traveling on these rails, several giant cranes straddle the trestle and do their work of placing the 8-ton buckets of concrete. Two of the cranes, called hammerheads because of their shape, are 72 feet high and have a boom, or arm, a block long. The other two cranes, called whirleys, are designed so they can revolve or whirl about in any direction. Two standard-gauge railroad tracks run along the deck of the trestle underneath the cranes. Seven 10-ton Diesel-electric locomotives move back and forth over the tracks hauling cars carrying bucketloads of concrete, feeding them to the relentless cranes that lower the buckets into place as needed. Reinforcing steel, cooling pipe, and materials other than concrete are brought out on a lower single-track trestle from which the materials can be picked up by the big cranes.

Canal Diggers

In the building of the miles of canals on the Central Valley Project, two special machines were put in use to speed the work after the ditches were dug to rough grade by big draglines. The first, a trimming machine, shaped like a broad U, is suspended

in a roughly excavated ditch, riding on two rails that are laid along each bank. By means of sharp-edged buckets that move on an endless chain, this machine trims or scrapes the earthen sides and bottom of the canal bed, leaving it neat, smooth, and the correct size. The second is called a concrete-lining machine. Its job, as its name indicates, is to line or pave the canal with concrete. It, too, moves along the two widely spaced tracks, spanning the canal laterally. By means of a hopper car the concrete is fed through a slotted chute to rapidly vibrating baffle plates. This vibratory or shaking motion settles the concrete and permits it to run down to its proper place. On the Contra Costa Canal, the concrete-lining machine, with three men, paved 3,000 square yards of canal surface in a day. If this machine had not been used it would have taken twenty-eight men four days to pave this area by the old hand methods.

The Raw Materials

We have read of the money, men, and machines needed to fashion the great stone fetters to chain the waters of the Great Valley. There is another all-important factor which still must be considered; what are the raw materials out of which men and machines create the Central Valley Project? In other words, how much of what does it take to build its giant structures?

To name all the materials used would make a very long list. Here we can only describe the most important materials and give the total quantity of each of these used. This will help to give some idea of the huge proportions of the job.

Aggregates

On the entire Central Valley Project it is estimated that over 15,000,000 tons of aggregates—sand and gravel—will be required for mixing with cement to make concrete. Everyone knows what sand and gravel look like whether one lives at the seashore or in the mountains, in the country, or in the city. But not everyone knowns how sand and gravel were formed and why they are conveniently placed along river beds and streams.

Sand, gravel, boulders, and all the smooth and rounded rocks that are strewn over the face of the continent were made hundreds of thousands of years ago during that long, cold, ice-age night before the dawn of the world, when great glaciers ground their screeching way through the deepening valley, picking up billions of tons of earth and rock and carrying them along, wearing their rough edges smooth and grinding and polishing their surfaces. Under the glaciers and imbedded within them, the billions of tons of sand and gravel were carried along as the mighty mile-thick sheets of moving ice thrust their way down to the sea.

Both Shasta and Friant dams, like all the great modern dams, are built of concrete. Concrete is sand and gravel (aggregates) bound together by cement.

In the course of centuries, as the earth's climate grew milder and the glaciers began to melt and rivers were formed, untold billions of tons of sand were carried down to the ocean, forming the sandy and pebbly beaches; and billions of tons more of sand and gravel were spread along the riverbanks. It is these deposits or aggregates that man discovered and put to work.

Five sizes of washed and graded aggregates were required for Shasta and Friant dams—one of sand and four of gravel—ranging in size from 3/16 of an inch to 6 inches in diameter. More than ten million tons of aggregates are used at Shasta, and the price for digging, washing, sorting, milling, and transporting them over the belt conveyor is 41.88 cents a ton. More than three million tons are used at Friant. At Shasta, the sand and gravel deposits are 12 miles downstream from the dam site. At Friant, the deposits are three miles below the dam.

Cement

The second most important ingredient in terms of quantity is cement—that simple, yet rather mysterious product which binds sand and gravel together, forming artificial rock stronger and more solid than any found in nature. This rock is called concrete.

The equivalent of more than forty million bags, each weighing 94 pounds, will be used in the building of the Central Valley Project, and this great quantity, which would require a train of more than 30,000 freight cars—a train 282 miles long and needing 555 powerful locomotives to move—will be manufactured almost entirely in California. One cement order for 5,800,000 barrels, placed by the United States Government for Shasta Dam, was the largest single cement order ever given.

When the Treasury Department received bids for the 5,800,000 barrels of cement for Shasta Dam, the lowest bid was from a company which had never been in the cement business; its price was $1.19 a barrel—$6,907,000 for the lot. This company got the immense order. It immediately began to erect a modern plant with the newest and most efficient machines near an almost inexhaustible supply of the ingredients, clay and limestone.

How is cement made?

Limestone is the most essential part of cement. Broadly speaking, limestone plus sand plus clay plus gypsum, heated, crushed, and ground, equals Portland cement. Limestone was built up from the remains of prehistoric plants and animals through many centuries. In making cement, after the limestone is blasted loose and scooped up by power shovels it is crushed by powerful jaw crushers that can crush a rock as big as a piano. The small rough chunks are then pounded into smaller pieces in a hammer mill, measured quantities of clay and slag added, and the rocky mixture ground and reground until it has the texture of fine dust.

Now it is ready for the fire. Heat, 2,700° F, so intense that it would consume a tree instantly or melt the hardest steel, is used to melt the mixture and burn away impurities.

Burned to the clinker state, with gypsum added, the mixture is altogether changed, both chemically and in appearance. It is harder than the rock it came from. It is ground again, as in the early stages of preparation, in a shot mill which breaks the clinker into small particles like grains of sand and in a rod mill

that finishes it to a powder finer than most flour, so fine that it will pass through a silk screen tight enough to hold water.

This is how the cement is made that will bind the vast structures of the Central Valley Project together: fine textured so it will adhere to the uneven surface of the aggregates and uniform in quality so that there will be no weak spots.

Steel

Of the many products that go into the project, steel is one of the most important. So frequently are the dams and canals referred to as concrete structures that the many thousands of tons of steel that go into them are sometimes forgotten.

Why is steel put in concrete?

Steel is imbedded in concrete to strengthen it and to tie the mass together. Concrete alone is very strong: one cubic foot will support a loaded boxcar. But concrete reinforced with only 6 per cent of steel will support several loaded boxcars.

Reinforcing steel is used in parts of Friant and Shasta dams along with many tons of steel tubing and fabricated steel which are buried within these mountains of concrete. More than 35,000,000 pounds of steel bars are used to reinforce portions of the dams, the powerhouse, the spillways, the canals, the pumping stations, bridges, tunnels, and many other structures of the project. Placed in both horizontal and vertical positions and wired together at points of contact, these bars form what looks like an immense wire fence. When the concrete surrounds this fence, the bars become the steel backbone of the concrete mass, adding greatly to its strength. Once imbedded in concrete and protected from the air, steel does not rust or deteriorate, but remains as strong as when first installed.

What other kinds of steel are used in the Central Valley Project? Part of the great steel bridgelike trestle constructed at Friant Dam for the placing of concrete will be buried within the dam itself. Each day the concrete will rise higher and higher, concealing the legs of the trestle forever from view. The same

kind of structural steel was used to build the Shasta cableway towers.

More than 11,000,000 pounds of steel tubing—about 1,800 miles of it—will be buried within the two dams to serve as coils to carry cool river water which will lower the high temperature of the quick-setting concrete.

More than 20,000,000 pounds of steel drum gates and other control devices will be installed at Friant and Shasta, and thousands of tons of trashracks, penstocks, outlet pipes, and other steel products will go into the completed dams.

Then there are the nine steel bridges being erected near Shasta for the rerouting of the railroad and highway, including the great double-decked Pit River Bridge, which alone will require more than 16,000 tons of steel. More than 5,000 tons of new steel rails will be used to reroute the railroad line around the Shasta Reservoir. The total for all the bridges is 30,000 tons of steel. The total for the entire Central Valley Project is 170,000 tons.

Other Materials

The quantities of other materials used on the Central Valley Project sound like figures from some astronomical calculation.

Seventy million board feet of lumber will be used to make the forms to hold the concrete while it sets. Twenty-five hundred acres of forest had to be cut down to make this amount of lumber—enough for the building of more than two thousand five-room homes.

About 3,200 tons of explosives will have been used on the project, and about 200,000 tons of fuel, coal, and lubricants. Millions of kilowatt-hours of power will be used to run the machines and to furnish lights during the time of building.

The list of construction materials at the dams and canals include thousands of lesser items of infinite variety—kegs of nails, tanks of oxygen, dishpans and water pails, tractors and trucks, industrial diamonds by the dozen and X ray film by the

case, sponges and chalk line, hard-shell hats and safety belts, hacksaw blades, jackhammer bits—even fishpoles!

These, then, are the ingredients. The recipe for this far-flung project would read something like this:

Take 15,000,000 tons of aggregates,

Add 40,000,000 bags of cement,

Place 170,000 tons of steel,

Season with electric conduits, water pipes, and miscellaneous machinery,

Put 5,000 men to work mixing well;

When mixed, place within the confines of more than 70,000,000 board feet of forms and let set.

Soon you will have the great Central Valley Project.

WHERE SHALL WE BUILD?

Before work could begin on the Central Valley Project those in charge had to decide where to locate the two great dams, the canals, and the other units.

In selecting the site for each dam they had to keep the following requirements in mind: a great mountain valley to become a reservoir when dammed up, a location in the narrow part of the valley so that the dam would not be too long or cost too much to build, a foundation strong and firm enough to support the mountain-size concrete dam, hills surrounding the valley high enough so that the water of the immense reservoir would not flow out at some low spot, a site on the river where the stream flow would be sufficient to provide an ample supply of water.

Another problem to be met arose from the fact that the thousands of acres of land which would be flooded when the river was dammed belonged to private owners and so would have to be appraised or valued and bought by the federal government; and if there were any towns or villages in the area, they would have to be removed to some carefully chosen and equally good location. Finally there was the very complicated question of water rights to various parts of rivers and streams affected by dam construction to be settled.

After the surveying of many suggested locations on the upper reaches of the Sacramento, the choice for Shasta Dam finally narrowed to three sites: the Table Mountain site between Redding and Red Bluff, the Baird site near the confluence of the Pit and McCloud rivers, and the Kennett site 12 miles north of Redding in the Sacramento Canyon and 5 miles below the merging of the Pit and Sacramento rivers. As early as 1935 the Bureau of Reclamation began explorations at these three locations. Engineer-geologists pushed the work forward, honeycombing the earth, delving, boring, probing for signs of decomposition, weakness, and faults.

At Kennett, hundreds of 2-inch holes were made, some as deep as a city block. Day after day diamond-set rings whirled about, cutting through the earth, through the top layer of decomposed and weathered rock, down, down to the solid greenstone. And from these holes were taken rock core samples, slightly larger than broom handles. These cores were marked to show the depth from which they came and then were carefully packed and sent to the laboratory for tests and examination. Geologists studied them for cracks and flaws, to determine their stability and strength. More than 11,000 lineal feet—over two miles—of these 2-inch borings were made at Kennett. And all over the site many test holes were dug.

But this was not enough. The engineers had to be absolutely sure that there was a solid support for such a huge dam. Thousands of feet of tunnels were dug under the river and under the base of the proposed dam. Engineers and geologists studied the tunnel walls to determine the general geological formation of the rocks, looking for signs of water seepage, percolation, and sheering characteristics.

But even this was not enough. Huge calyx (flower-shaped) hollow drills, with chilled-shot cutting edges, began boring away, grinding, cutting holes 3 feet in diameter fifty feet deep into the million-year-old stone. The cores were removed, round and smooth, looking like petrified trees, and were examined by the scientists. The scientists themselves went down

into these yard-wide holes, to test, chip the rock, and examine the earth from the inside. Innumerable tests were made; various Bureau of Reclamation experts contributed recommendations; the records of United States Army Engineers and the reports of the California Division of Water Resources were considered; the California Water Project Authority and the Board of Consultants of the Bureau of Reclamation rendered their opinions. At last the Kennett site was pronounced safe and suitable.

The Board of Consultants for the Bureau had stated that any of the three sites were suitable for dam construction. The Bureau selected the Kennett site because "it was superior from an economic standpoint" and would cost less to build. Shortly after its selection the Kennett Dam site was renamed Shasta for the majestic Mount Shasta which looms up 14,161 feet in the distance.

In this same careful way, with all the tools of modern science and the skills of many branches of engineering, the Friant Dam site was selected on the upper San Joaquin River, 20 miles north of Fresno and the same distance east of Madera.

WORK WITH A BIG W

The Central Valley Project is made up of two huge dams, about 350 miles of main canals, a hydroelectric power plant, more than 200 miles of power-transmission lines, and many accessory structures such as pumping plants, bridges, and tunnels. Each is located to serve its part in adjusting and conserving the water supply of the great Central Valley. Knowing the name of each principal part will aid in fixing its location.

Shasta Dam and power plant are on the Sacramento River, 12 miles north of Redding. Friant Dam is on the San Joaquin River, 20 miles north of Fresno. The main water carriers, besides the two rivers, are the Delta Cross Channel, Contra Costa Canal, San Joaquin Pumping System, Madera Canal, and Friant-Kern Canal. And the project includes the Shasta Power Transmission Line, stretching from Shasta Dam 200 miles south to a substation at Antioch.

If a man walked 20 miles a day it would take him over a month to inspect all the far-flung project, from Shasta Dam to the southern tip of the Friant-Kern Canal.

The Job Begins

The surveys had been made and the plans drawn, the money had been provided, houses for the workers had been built, materials were being prepared, and equipment was being delivered. The time had come to start construction.

Early on the bright, hot morning of September 8, 1938, a small gang of men began the actual building of Shasta Dam.

There was no crowd of spectators in attendance. The exact time the excavation would begin was not known even to the contractor. The machines used to grade roads down the steep canyon walls to the dam site were the same machines that began removing the overburden—the first loose topsoil above the foundation rock. The transition from road-building to damsite excavation was imperceptible. On September 7, the foreman remarked, "It looks as if we'll be ready to start in the morning." And that was the extent of speech making when work began.

Starting on the east bank, 250 feet above the greenish, curling Sacramento, two 4-ton scoop shovels lowered their heads and bit up their first taste of earth from the Shasta Dam site. A power-shovel operator grinned and waved to a truck driver as he expertly swung the scoop around. A lever was pulled, the scoop-bottom opened, and earth, rocks, and silver-leafed manzanita brush fell into the waiting truck.

Scoop-scoop—take it away. Scoop-scoop—take it away. That was the rhythm of the work as through the hot, dust-laden air a small hole in the ground became visible. Nearby a crew of carpenters was completing shop buildings and a construction camp. Another crew of workmen was clearing manzanita and other brush from the dam site.

A few weeks after the job was started, three immense 6-ton electric shovels arrived and went to work; and a fleet of eighteen

big new trucks with extra-large steel bodies and overhanging visors to protect the drivers from falling rocks moved in and took over. Five quick bites and the giant scoops had filled these trucks to overflowing, ready to roar away over the steep new roads to the waste piles—called "spoil banks" in construction language.

October 22, 1938, the ground-breaking ceremony was held in Redding. Here crowds gathered to hear the dedicatory speeches and to see the visiting state and federal officials.

But at Shasta the work went on.

Some visitors went to the dam site to see this long-talked-of project—dust, load, dump, dust—and departed. Other visitors came; the work went on. And after days and weeks and months the insignificant hole-in-the-ground became distinct against the towering canyon walls.

Five scoop shovels and a fleet of thirty trucks dug into the steep banks on both sides of the river, removing the loose boulders and earth. And "cats" (caterpillar tractors) guided by tanned and wiry "catskinners" (drivers) pushed the overburden from the upper strata of rock.

Drillers and Dynamiters

Up on the face of the canyon wall, high above the river, the "high-scalers" sway in midair. They are the daring drillers who climb, or scale, the sheer cliffs to do the preparatory work for blasting out a level landing or "working table" from the solid rock so that the wagon drills can move in. "High-scalers" also are used for drilling in spots so steep and inaccessible that only men, and not machines like the wagon drill, can work there.

Suspended in bosun chairs the "high-scalers" grip their whirling, vibrating jackhammers and force them cutting and hammering into the stony barrier. The bosun chairs are the same sort sailors use when they paint the side of a ship, rather like the swing hung from the limb of a tree out in the backyard. They are fastened to the rocks high overhead.

In their precarious seats the "high-scalers" push forward their hard and dangerous work. With silver-colored metal safety helmets to protect them from falling rocks and make the sun's burning rays more bearable, they hammer their way into the earth's crust. Danger threatens below as well as overhead. Sometimes a man's footing breaks loose, leaving him suspended in the air, his heavy, speeding jackbit twisting and whirling wildly. Each time they change drills the "high-scalers" "blow the hole" with opened air line, sending the powdered rock dust geysering into the air. Jackhammer operators and the men handling steel bars and picks pound and drill their way in, prying loose huge pieces that fall away and down the slope, sending up great clouds of dust.

When the working table is prepared on the canyon side, a fleet of wagon drills arrives. Guided by their operators and chuck-tenders, the drills begin breaking their squirming, twisting, screeching way into the tough rock. This rock is called Meta-Andesite by the geologists; it is hard, greenish-gray rock of volcanic origin. It is much older, tougher, and more difficult to drill than the rock, the Breccia formation, encountered at Boulder Dam. The drillmen do not bother much about the names or histories of the rock they struggle to pierce. What they want to know is: how quickly is this rock going to wear out a steel bit?

Drill a foot or so and remove the bit for resharpening; drill a foot and remove the bit for resharpening, each foot of rock requiring about two minutes to drill. The holes at Shasta range in depth from 20 feet near the top to 4 feet near foundation rock and are spaced about 10 feet apart.

When a string or round of holes is ready for blasting, the wagon drills move on and the powder men, or "powder monkeys" as they are called, go to work. It is thrilling to see these men handling explosives—tons of explosives on a job of this size. Of course they understand the risk, but they know their business; completely sure of themselves, they handle the sticks of dynamite as though they were pieces of firewood.

Carrying their 50-pound cases of dynamite, the "powder monkeys" move along from hole to hole, loading each according to its depth, the 20-foot holes taking about 50 pounds of explosives. When one hole is loaded they move on to the next, loading, tamping, and connecting each charge to the "buzz wires"—lines which are strung from one charge of explosives to the next. At the bottom of each hole is a stick of dynamite called a primer, containing a delayed-action cap. When the round of several hundred holes is hooked up, all is in readiness.

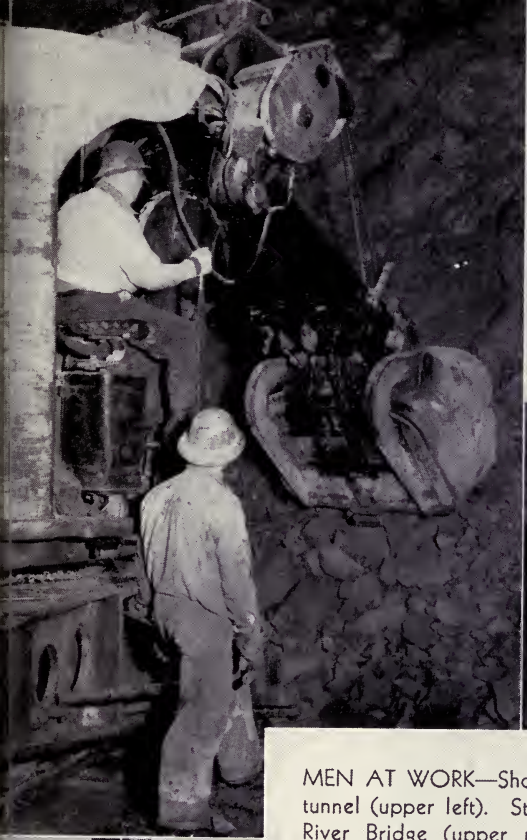
The short, sharp blasts of the shift whistle sound above the roar of wagon drills, air compressors, power shovels, humming cable, and the general thud and clangor of construction.

The workers move quickly out of range of the explosion, piling into waiting trucks that take them to the camp where they live. The next shift has not gone to work, but awaits the shock at a distance. It is near the zero hour. A final careful examination of the entire danger zone is made by the shifter or foreman. Everyone is clear. The switch is pressed, sending 240 volts of electricity through the line.

Zoom—Zoom! The earth shakes and a tremendous roar echoes back from the canyon walls. A barricade of rock lifts from the ground and for an instant seems to remain suspended in the air, then settles to the earth in a clatter of falling stone and rolling clouds of dust.

But that was only the first blast. About three-fourths of a second later, when the element in the delayed action cap has burned through, a second great roar drowns out all other sound, shaking the air as it seems to recede over the towering horizon. Once more the rocks lift high and settle earthward, sending out a pall of dust.

The great tide of sound ebbs and flows. Again and again the charges explode at brief intervals until all twelve delays have been fired. One contact of the switch and the rocks have showered upward for ten seconds until the entire round has done its work—and some three hundred holes have been "shot."

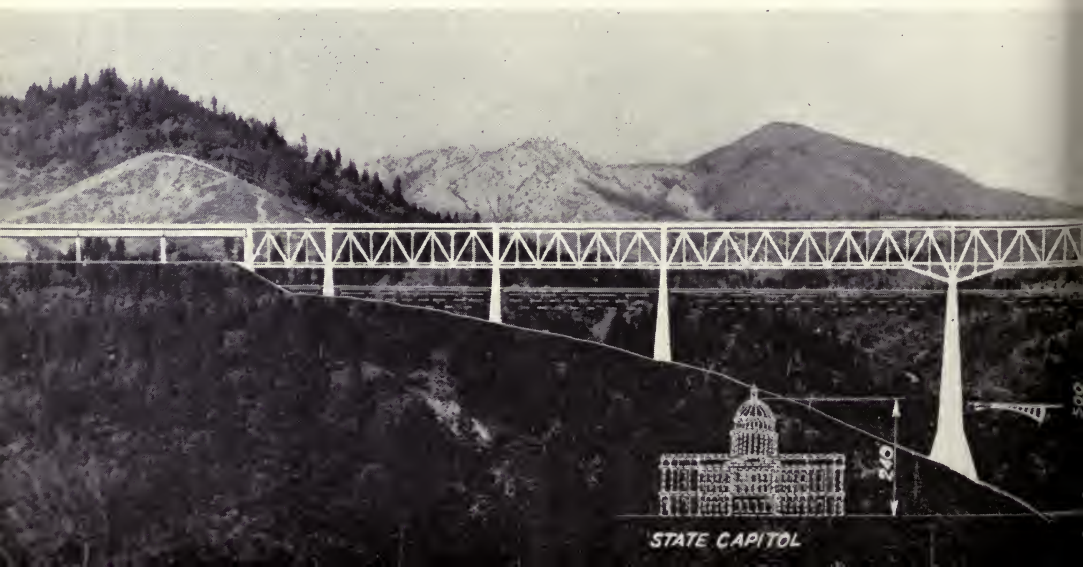


MEN AT WORK—Shoveling muck out of a tunnel (upper left). Steel riggers on the Pit River Bridge (upper right). Wagon drills sinking dynamite holes (lower left). Dumping a bucket of concrete at Friant Dam (lower right).

RAILROAD RELOCATION—Twelve tunnels and eight majo bridges were built to relocate a mai line railroad around Shasta Reservoi

A view of tunnel.

PIT RIVER BRIDGE—The world's highest double-deck bridge carries a four-lane highway and two railroad tracks across part of the reservoir.



Section of bridge.

DAY AND NIGHT—Work goes on twenty-four hours a day at Shasta Dam These views are from the same point on the east abutment.

FROM THE AIR—A view up the canyon shows: (1) The concrete mix plant; (2) giant cableway head tower; (3) one of the tail towers; (4) part of the rising dam; (5) powerhouse under construction; (6) Vista house for visitors.

In this one furious round of blasting about 15,000 pounds of explosives have been used, the force of which broke loose and lifted nearly 12,000 cubic yards of rock.

Twice a day, usually at the end of the day shift at 4 P.M. and at 12 midnight between the swing and graveyard shifts, during the entire period of excavation, these tremendous chains of explosions shook the upper Sacramento Valley.

These "powder monkeys" know what can and what cannot be done with explosives: they respect its power, they know the hazards of their occupation, they are careful. The Shasta construction job has a good safety record.

When the dust has settled and the far-flung echoes have died away, the next shift comes on, and the lumbering scoop shovels begin to load the shattered rock into the waiting trucks.

And so the excavation goes on—scoop, drill, blast, scoop—until more than 4,000,000 cubic yards of material have been removed and in the yawning east and west abutments the hard bedrock is reached.

The excavation at Friant Dam was a similar process. The amount of material removed totaled about 1,300,000 cubic yards.

Grouting

When the foundation for Shasta Dam is cleared and the Board of Consultants and the Bureau of Reclamation engineers have approved its depth and strength, have examined the fault angling across the site, an unusual kind of job called grouting still must be done before the order is given to pour concrete.

Grouting is the sealing of all cracks and tiny flaws in the natural rock by pumping grout, which is cement and water, into the seams formed millions of years ago when the molten rock solidified, cooled, and shrank.

But even before grouting begins, the "dental work" as the workers call it must be done: any remaining fragments of shattered rock must be pried loose and the soft spots in the foundation must be gouged out. Then the hydraulic monitors—high-

pressure nozzles—spray thousands of gallons of river water on the exposed rock, washing its surface and blowing away all broken stone and particles of dirt.

The natural rock of the foundation appears hard and solid, yet it is not good enough to meet man's rigid standards. It must be bound together into a mass equaling in strength the man-made rock, concrete. At both Shasta and Friant for many weeks grouting went on. Special holes were drilled into the foundation and into the seams. Under high pressure, "pumpcrete" operators forced grout into every crack to a depth of 200 feet. The filled grout pipes stuck up from the twisting seams like broken fence posts, looking out of place in the clean, bare foundation.

After two years the work of preparation was complete. Hundreds of men who had worked on the excavating went away. Other men took their place, men with experience for the next great task. The time had come to pour concrete.

The Foundation is Ready

From the crest of a hill overlooking the east abutment of the Shasta Dam site, the slightly curved foundation site stretches like a giant trench across the river to the west, 3,500 feet in length and gouged as deep as 300 feet. This huge, gray scar on the rolling hills looks too immense to be man's handiwork. It seems like some wild slash across the landscape made by the rough and purposeless hand of nature. Man is dwarfed by the scattered rocks. Even the machines, the trucks, and the scoop shovels scattered in the foundation, seen from above, look insignificant, like grains of sand and bent match sticks. The only impressive man-made thing in range of vision is the cableway head tower, standing like a great unproductive oil derrick on a landing across the canyon.

To the left beyond the river, ten red cement "silos" stand new and ready. The diminutive railroad track paralleling the river twists away downstream. A mile below, the age-blackened

buildings of Coram, an abandoned copper town, stand deserted on a leveled hill. No smoke issues from the squat chimney of the smelter—it has been quiet many years—but the raw, scorched earth for miles around, the leafless long-dead trees, standing and fallen, give mute evidence of a long period of wide-spreading acid fumes belching forth and destroying all vegetation.

Cutting through the foundation is a placid stream of water, the Sacramento River, reflecting the white clouds overhead. Here in midsummer the Sacramento is a peaceful river giving no sign of the havoc it wreaked at the Shasta Dam site in the spring of 1940, when, rising 43 feet to an unprecedented peak, it swept away three new bridges, each playing a part in the building of the great concrete dam.

Terracing the receding hills on both sides of the canyon, many roads wind and twist away to the waste piles and to the new towns where the workers live. Upstream, on the hazy northern horizon, snow-sheeted Mount Shasta continues her million-year watch on the Central Valley, towering above man's great effort to change his environment.

On this hot July day a small bird wings over the dry, brush-dotted hills and slowly circles the gaping hole in the earth. It is strangely quiet in this place. Some men move about below, but with an air of expectancy. One can almost sense some great development.

This is that important day in California's history, July 8, 1940—the day when the first bucket of concrete is to be poured in Shasta Dam. Here is a dream come true.

The First Concrete

For many weeks the great belt conveyor had carried its daily load of thousands of tons of aggregates from the deposit near Redding to the stock piles above the river at the dam site, building up reserves so that once the mix plant started no breakdown or emergency would stop the flow of sand and gravel to the revolving monsters.

The cement "silos" near the stock piles, each holding 5,550 barrels, were filled and awaited only the push of a button to start blowing their contents up the western hillside to the mixer.

The day before, word had been telephoned to the mix plant to have the first batch ready by ten o'clock. "Drop the first bucket in Row 38 at 10 A.M.," was the long-waited order.

The supply bins in the top of the round, six-story mix plant had been filled with cement and all sizes of gravel and sand long before.

At 9:50 A.M., the concrete-mix operator pressed a switch on his complicated panel board and with a violent and overpowering roar, cobble—coarse, medium, and fine gravel, then sand and cement dropped down the metal chute into the number-one mixer; water shot into the drum; and the total of each was weighed exactly on the automatic scales and printed on the record tape—all automatically.

Like huge gray elephants arranged in a circle, the five concrete mixers stood ready for their long task. Only number one was rolling and its mix of 12 tons fell noisily about in the slowly rotating cylinder. Compared with the attendants working nearby, these mixers seemed tremendous machines; but compared to the great hole to be filled, they seemed miniature toys totally inadequate for their job.

At 9:55 A.M., the first batch was ready. An inspector had approved the mix. The operator shouted excitedly through the telephone to the engineer of the endless railway. All was ready.

The mixer came to a noisy stop, tilted and spilled its moist load through a collecting cone in the center of the floor and down into the waiting "goose," a new and spotless receptacle on a car of the circular railway. A sample of this first batch of concrete was taken, as thousands would be taken in the future, and the sample bucket was marked so the laboratory technicians could identify it.

At 9:59 A.M., a small but shrill train whistle sounded and a car of the endless railway made the first of its hundreds of thousands of trips around the circular track. The engineer

grinned; it was good to get down to work. At the loading dock the car passed and the curved bottom of the "goose" opened and dumped its important load into the huge bucket suspended from the cableway.

High in the head tower, seated at his controls, the operator of number-three cableway awaited the signal, a set of headphones clamped to his ears. Down at the loading dock the hook tender waved his arms, signaling "take it away." With accurate fingers the operator pulled the proper lever.

A thousand eyes watched the cable bend under its burden as the square bucket swung up and out over the excavation, suspended from a twenty-four-wheel carriage rolling along the cableway, straight and true toward the place prepared, Block C, Row 38, in the east abutment. When directly overhead it stopped, a foreman motioned his directions to a "whistle punk"—a radio signalman—seated on a projecting rock, the signalman spoke into a portable microphone, and the message to "drop her down" was flashed by radio to the operator in the head tower. With constant guidance the 22-ton plummet settled gently into the base of Shasta Dam. A half-mile away in the head tower the operator pressed another lever, a cable drum spun, wheels in the cable carriage whirled, the bottom of the bucket opened and dropped its load. Though emptied of its 8 cubic yards of concrete the bucket was not immediately lifted, but hung there near the ground, posing for photographs. It was 10:02 A.M. A great cheer went up from the crowd. The first concrete had been poured.

At last the great barrier was begun. Mr. Frank T. Crowe, the contractor's superintendent, threw three new dimes into the moist mass "for luck," as a dozen "muckers" in hip-length rubber boots spread and settled the concrete over the clean, rocky surface. The single bucket of concrete seemed lost in this great cavity; from the visitors' observation point on the hill above, it was not visible. Even the metal-lined wooden form, about 5 feet high and 50 feet square, was an unimpressive speck in the foundation.

It took two shifts to pour the first "lift" in Block C, Row 38, near the Sacramento River bed, two shifts in which "muckers" tramped about in the wet mass which they called "mud," while their noisy, compressed-air vibrators, making the harsh noise of a riveting hammer, shook down and made compact the freshly poured concrete. But already carpenters were at work building the next section of forms, completing Row 38 the full length of its 400 feet. Simultaneously, the pipemen were installing the thin-walled pipe to cool the settling mass and the one-half-inch grout pipes to seal the joints.

This was the beginning. Now night and day, seven days a week, for more than four years these quick-moving buckets on the seven cableways make their fast flights through space from the loading platform to the slowly filling forms.

Cooling

Most visitors to Shasta Dam are greatly surprised to learn that concrete is not poured continuously in one huge wall, but is placed in successive lifts 5 feet high and 50 feet square, with the blocks or columns in each row raised alternately, like a great game of building blocks. To lock these blocks together they are "keyed"—made with corrugated sides that fit into the adjoining blocks. The corrugations, or "keys," on the sides of the blocks running cross-stream are horizontal; on the sides paralleling the river they are vertical.

Although the practice of placing many blocks rather than one massive block would seem to make a dam less strong and less able to withstand the side-thrust of the deep reservoir, this is the only practical method of building a dam. This is so because of the heat-creating chemical action that takes place in setting concrete.

Mass concrete mixed with water will generate enough heat after it has set to increase its temperature from 50° to 90°. If left to cool naturally it would take a great many years, perhaps a century, to reach a normal temperature. And because of the forces of expansion and contraction generated by this heat, the

dam would crack and shatter years after it was in use. The seams between the blocks give "elbow room" to the swelling concrete, serving as contraction joints. In other words, the cracks in the dam are controlled—made to occur only at these joints, which later can be filled with grout, like the tiny seams in the natural bedrock.

In order to speed this swelling-shrinking process, several methods have been worked out by the Bureau of Reclamation, among them being the use of low-heat cement. The Bureau determined by test the best formula for mixing, regulating the height of each lift, and controlling the rate of pouring concrete. At least seventy-two hours is required to elapse between placing successive lifts. The most important temperature-control device is a system of refrigeration first used at Boulder Dam.

This method called for the installation at Shasta of more than 1,200 miles of thin-walled steel tubing, spaced about 5 feet apart, through which river water would be pumped, dissipating more heat than 15,000 tons of coal could produce.

By this method each block can be cooled within five weeks, so that when Shasta Dam is completed its final temperature will be about 50° F.

This same system of artificial cooling was used for Friant Dam and for the largest piers of the Pit River Bridge on the Shasta railroad relocation, a feature of Shasta Dam.

View from the Head Tower

On a cloudy autumn day the sights and sounds of Shasta Dam fill the eye and ear. The half-completed dam stretches irregularly across the canyon and the varied and discordant noises merge in a roar that wells up and overflows the rim of the valley. The scene is much the same as on any day during the 48-month period of concrete-pouring.

From the platform atop the head tower the whole picture is visible; and although dwarfed in size from this height, the details of construction fit together more understandably.

BIRD'S-EYE VIEW—From the Shasta head tower, a workman looks across the canyon toward the east abutment excavation with a few concrete blocks of the dam in place at its base, and the mighty Sacramento River (looking like a mere creek from this height) flowing by in a diversion channel 700 feet below.

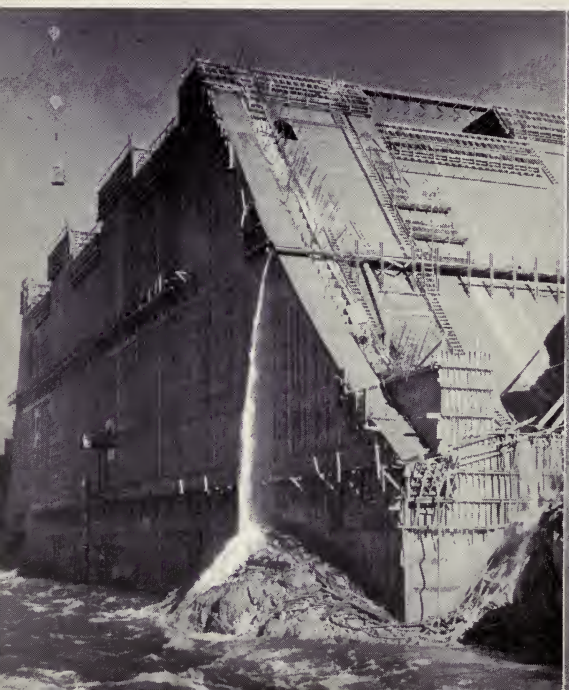
To the south the conveyor belt can be seen sliding down the steep eastern hillside, leaping the river, then moving upstream to the mix plant immediately below. Ten boxcars stand on the siding near the cement silos and a faint humming sound comes from the pump as it empties carload after carload of cement. The grating roar of the mix plant can be heard as the rolling drums fill and mix another and another and another batch. Directly below, a car on the endless railway creeps around its circle, dumps its load into the waiting buckets, and returns.

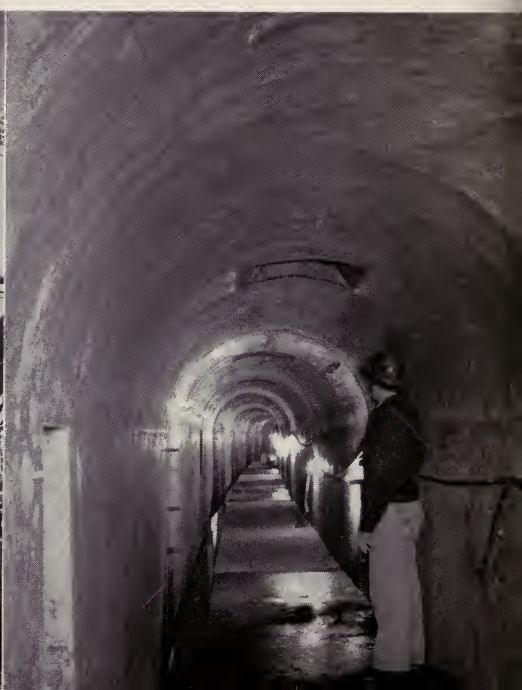
Across the river and downstream, the building housing the great air compressors and the pumps pulling the water supply from the river and forcing it up to the 3,000-gallon tanks stand in a draw behind the shoulder of a hill. A short distance away is the steel-bending shop where the reinforcing steel is bent to shape to support every opening in the dam and powerhouse. In the foreground below the dam the scattered buildings of the town of Shasta Dam (called "the Camp") are plainly visible—the building for the engineers and inspectors, the two-story building that houses offices for the contractors, the dormitory for single men, the commissary (eating place), and stores. Along the hillsides, electric power lines, air lines, and water pipes stretch like tangled cobwebs. At the top of the east abutment is the white Vista House where the public may watch the fascinating scene from a covered grandstand.

To the north and high above the river are some of the temporary industries essential to the building of a dam: the carpenter shop, where skilled men build the detailed and precise forms to shape the many openings in powerhouse and dam; the blacksmith shop, where the glowing furnaces heat the steel bits for resharpening; the concrete pipe plant, where the miles of porous drainage pipe are made; and the welders' and electricians' shacks. To the south, near Coram, is the penstock-fabricating plant where the great turbine pipes, 15 feet in diameter, are welded together.

MORE CONCRETE—The bucket is about to drop its 16-ton load of concrete in one of the blocks of Shasta Dam.

INSIDE AND OUT—The dam looks mighty solid on the outside (left) but it contains many passageways (right) called galleries.





POWER—Huge generators, like these at Boulder Dam, will produce electric power at Shasta Dam.

FOR DEFENSE—Electricity will be carried over transmission lines (right) to many national defense industries such as oil refineries (left).

FRIANT DAM—The spillway section in construction (upper). An artist's sketch of how it will look from the air (lower).

Following the twisting Sacramento River to the north where it makes a great loop, a sharp eye detects a few scattered buildings of the old copper-mining town of Kennett, soon to be covered with several hundred feet of water of the Shasta Reservoir.

On a level with the top of the head tower, 260 feet above the ultimate crest of the dam, the cables spread over the growing wall which rises over an area of twelve blocks every day. The cables vibrate and sing, sending a breath-taking tremor through the tower, as the concrete-loaded bucket makes its rapid flight to the east abutment, dropping down and out of sight of the operator, guided by the radio signalman and hook tender, to its final bed.

Near-by a skip (a metal body used to transport various materials) loaded with sand, and with skip tender riding, is lowered by number-three cable to a freshly poured block. Here it is dumped and the sand spread 4 inches deep over the entire surface, flooded with water, and left to serve as a wet blanket, to retain the moisture in the setting block.

In another row the muckers push their vibrators into the moist mass. The spent air makes a hollow explosive sound as the concrete settles and unifies. Near the center of the dam "form raisers" hammer and bolt a form together and oil its metal surface in preparation for the next pour. Near the western end, directly below the head tower, "form strippers," wearing safety belts, strip the form from a cool and solid block.

Near-by "pumpcrete" men place their concrete pumps, and with pressure gauges high, begin forcing grout into the seams which have been caused by contraction. Although the cracks between the blocks are only one-sixteenth of an inch wide, over the length of the dam they would total over 4 inches, too great a gap for the burden this dam must bear. As each level is completed, every crevice, every minute opening is pumped full of grout, sealing it into one monolithic block. Even the coil of cooling pipe, having served its purpose, is pumped full and closed forever.

While the work goes on, one shift of men sits about on a high row eating lunch. Everywhere catwalks lead from one huge block to the next.

Two hundred feet away air hoses stretch from the distant compressors to masked men holding air guns. Patiently, in the noise and heat and dust, they sandblast the marked surface of a block, cleaning and roughening it and removing loose particles. With tremendous force the air pressure hurls millions of grains of dry sand against the concrete, scouring and making the surface ready, so the next pouring will bind and unite with it.

And moving about over the entire dam are inspectors from the Bureau of Reclamation, watching, testing, examining, making sure that each foot of the structure is strong and durable.

Strung from the center cable, a great arc of floodlights reaches across the dam, and spotted about the hillsides, banks of shielded lights await nightfall to focus their illumination on a particular section of the work. Strategically located 1,500-watt lamps—2,000 of them—stand ready to make the scene like day.

Noise and dust ascend. The work goes on. Over the shoulder of a hill the huge SAFETY FIRST sign shows its message of caution.

Far below, a cloud of smoke billows from the diversion tunnel as a freight train emerges and grinds north, following the Sacramento. To the north, where sky and mountains merge, the cold, white face of Mount Shasta gleams above the lesser majestic peaks.

Seen from the head tower, the dam site appears in all its immensity: this is labor on a grand scale, purposeful, planned, and magnificent.

On this 460-foot tower man can look the mountains in the eye and, feeling his power, seem more equal to the task of reshaping nature.

The Dam Inside and Out

Since every aid of science and engineering is being used to make Shasta Dam a solid, unified mass, it seems strange and

contradictory that it is not solid; in fact, an X ray would reveal that it is honeycombed with galleries, elevator shafts, chambers, conduits, penstocks, and concrete drains. Only 1 per cent of the total volume is space, but every hollow inch is there for a definite reason.

As the concrete pouring goes on, carpenters place plywood-covered arch-shaped "forms" at each 50-foot level to shape the galleries, and steel workers put bent reinforcing bars about the forms to strengthen the long, cool passageways that will run lengthwise and crosswise in the dam, from one end to the other and from top to bottom. When the moist concrete is poured it covers the steel and shapes itself about the forms, leaving these inspection tunnels ready for use.

Other galleries are made running lengthwise in the dam from the left abutment to the right, connecting with the transverse galleries by circular stairways. Near the base of the dam, a foundation and drainage gallery 5 feet wide and 7 feet high follows the irregular contour of the dam base and extends into the foundation rock for a distance of 500 feet on each side of the river. Connecting with this foundation gallery is a network of 6-inch porous drain tile running through each block, 13 feet in from the upstream face of the dam, forming a drainage system to carry any water seepage down to the foundation gallery, from which it is pumped up and out of the structure.

Will water seep into the dam? Yes. It is known that a certain amount of water will penetrate through the hundreds of feet of concrete and through the grouted foundation, but this has been taken into consideration. Months before work was begun, exploration tests were made to determine how much water would be forced through the gray-green Meta-Andesite rock. As a means of controlling the amount of seepage, hundreds of holes were drilled on a line following the upstream dam face and a rich cement-and-water grout was forced 150 feet down into the cracks and seams, forming a curtain, or watertight wall within a wall. But there was a limit to the depth of the grout curtain, and it was known that some small amount of

water would find its way down and under the grouted barrier. The problem then was to control and direct this persistent trickle of water into the 19-mile drainage system of the dam. Although only a few gallons an hour seeped in, this amount, if not released, would be enough to set up a tremendous lifting pressure which might some day force up and weaken the entire structure.

To release this pressure, weep holes were placed through the walls of the seventeen galleries in the dam and the seven tunnels in the foundation rock of the east and west abutments, so the water could trickle down like tears and find its way into the drains.

As the work of concrete placing went on, in Rows 38 and 46, near the center of the dam, carpenters made forms in each 5-foot lift to shape the elevator and hoist shafts that would hold these modern devices, moving passengers and equipment up and down their 400-foot guide rails, at each level connecting with the galleries that stretch cool into the distance.

Yet these are not all the holes or openings in Shasta Dam. Near the center, about 200 feet from the base, four steel-lined conduits reinforced with heavy ribs are placed, leading right through the dam from the upstream face to the curving spillway on the downstream side. Each of these conduits is 8½ feet in diameter. Their purpose is to let water out of the reservoir into the river as desired: water is sometimes needed downstream in addition to that released through the great turbines. About 100 feet above, eight more of these great conduits are placed and imbedded in concrete. Near the top of the dam, more than 400 feet from the base, six more of these outlets are placed, spaced about 50 feet apart. These eighteen river-control outlets will be used to release water from Shasta Reservoir, in a regulated flow, in accordance with the needs of the Central Valley Project. Also, during seasons of heavy rains and melting snows, part of the excess flow will be released through these river outlets. In times of extreme high water, flood flows will be passed over the central spillway.

How is this tremendous force of water controlled? What will prevent floating trees, logs, and other debris from blocking up the outlets?

Within each conduit are high-pressure hydraulic tube valves, each weighing 10,000 pounds, permitting the operator to open or close these great gates simply by pressing a button.

On the upstream side of each outlet, a great trash rack about 60 feet in height is fastened to the side of the dam, screening the opening and keeping all floating matter in the reservoir.

But even these are not all the openings in Shasta Dam. On the west abutment five great pipes, called penstocks, more than 15 feet in diameter (large enough to drive a truck through), will carry a hurricane of water to the turbines with a capacity of 515,000 horsepower that generate electricity.

This is what the towering mass of concrete that is Shasta Dam will look like on the inside. With almost 5 miles of galleries, with elevator shafts, circular stair wells, and drum-gate control chambers formed in the everlasting concrete, with eighteen great outlet pipes and five penstocks embedded in the mass and passing completely through the dam, and with a drainage system extending to every part of the monolith—this is Shasta Dam, not quite so porous as a sponge, still much stronger than a rock. This strength will hold back the waters.

The Final Touch

Stage by stage and block by block the concrete reaches toward its maximum height 560 feet above the Sacramento River bed.

On that day in 1944 when the concrete buckets have taken their last ride, when the "muckers" have pulled their vibrators out of the last towering block for the last time, when the shift whistle has made its last deep-throated blast, the concrete men will jump their last ride on a truck passing to the camp, to the dormitory, for the last meal and the last clean-up. Their work will be done.

Then only the roadway across the top of the dam will remain to be surfaced, the wide tracks for the traveling crane to be put in place. The railings and the ornamental lights already will be there.

Only the "riggers" will be at work installing the three huge 28-by-110-foot drum gates that will control the flow over the spillway. Under the spillway bridge, in the three openings prepared for them, these 600-ton gates will be bolted into place. Each gate, shaped like a quarter of a circle, will sweep up and hold over 34 feet of water behind its riveted surface, bringing the reservoir to its maximum height, at 1,065 feet (above sea level) at flow line. When lowered, these great steel barriers will turn down into their chambers concealed from view. The drum gates are for emergency use only. Most of the water released from Shasta Reservoir will pass through the power penstocks or the river outlets. But occasional heavy flood flows will swamp over the crest of the huge spillway, at a possible peak of 187,000 cubic feet per second, falling 480 feet down the concrete slope to the river below.

Shasta Dam, built to outlast the mountains, will be ready.

Shasta Powerhouse

During the years of building Shasta Dam, work on the other important parts of the Central Valley Project is going forward.

The seven-story Shasta powerhouse below the dam is being built and four of the main generators of 75-kilowatt capacity are being installed, with provision left for the addition of one more unit of the same size.

From the time of placing the steel anchors deep in the rock and concrete to hold the penstocks secure and vibrationless (when the great surge of water cascades down and around the spiral casings of the turbines) to the painting of the railing on the observation balcony, work progresses with hardly a hitch.

The turbines and generators are connected by vertical steel shafts or rotors, each weighing 450 tons. When the water of

Shasta Reservoir is admitted to the penstocks, it will roar down into the great turbines—each of them of 103,000-horsepower capacity—and when the turbines start whirling they will automatically turn the big generators, each of which will constantly produce 75,000 kilowatts of electricity. This electricity will go to the five main transformers mounted on their platform. Electric cranes for installation and repair work, with 250-ton capacity, are to be provided on high tracks. All the thousand and one switches and control devices of a complex and mysterious powerhouse will be connected, ready to do their part in transforming the force of falling water into the force of lightning-like electricity.

Every inch of this modern powerhouse, from the graduated penstocks to the curving concrete bays, shows evidence of great engineering precision—all this to make possible the operation of the project and the repayment of part of its cost through the sale of electric power.

And from the powerhouse the steel towers of the transmission line will march away 200 miles southward to Antioch, strung by those linesmen who do their work with swaying high tension lines and glistening insulators and label their effort high voltage.

Rerouting Highway and Railroad

In the building of Shasta Dam one difficult problem was the relocation of portions of the main north-south Pacific Highway and the Shasta Route of the Southern Pacific Railroad.

The railroad, which for more than sixty-five years had followed the twisting Sacramento Canyon, past the dam site, to Kennett and beyond into Oregon, followed a route which for many miles was now to be submerged under the great Shasta Reservoir.

To enable work on the dam to progress, a temporary by-pass tunnel was driven for 1,820 feet through the west abutment under the dam foundation. This was one of the earliest jobs at the dam site, and it took eight months to complete. It

was dangerous work. When the tunnel was bored and lined with concrete, tracks were laid through it and the railroad began using this temporary route, passing under, instead of across, the actual dam site.

This diversion tunnel had a twofold purpose. For about two years it was to serve as a temporary by-pass for the trains while the permanent railroad relocation was being constructed around the entire reservoir site. After the railroad was rerouted over its permanent high-level line, the tunnel at the dam site would carry the swirling waters of the Sacramento River while concrete was raised in the dam. But even this was only a temporary use for the tunnel. When its diverting work was done, great concrete plugs, each more than 32 feet thick, were to be placed side by side in the tunnel, making a solid wall 162 feet thick and sealing the tunnel forever.

The old roadbed across the dam site was torn up by the excavators while the permanent relocating of the railroad and highway around the reservoir went on.

The new railroad high line, far above the future water level, crosses the Sacramento River near Redding and, swinging on a half-circle to the east, heads north for the Pit River. On this 30-mile route through rugged country, twelve tunnels were holed through and eight major bridges were built. The most important of these is the Pit River Bridge, 8 miles above Shasta Dam, where the railway and highway meet.

This bridge is a double-decked structure crossing an arm of the reservoir—the highest double-decked bridge in the world, one deck being more than 500 feet above the water of the river. The lower deck, 3,590 feet long, carries two railroad tracks; the upper deck, four lanes of highway traffic and two walkways. Requiring sixteen months to build, the bridge leaps from wall to wall of the canyon, with 500 feet of water beneath its central span, when the reservoir is filled will be 500 feet of water.

The old Pit River bridge, a pygmy by comparison, located upstream and far below near the river, will not be removed, but will be covered by the cool waters of Shasta Reservoir.

A Network of Canals

About 30 miles below the city of Sacramento, on the Sacramento River, near the town of Hood, the pumping station of the Delta Cross Channel will lift a great stream of seaward-rushing water and let it flow southward through miles of dredged delta channels to the San Joaquin River. The job of creating the cross channel and its pumping station is not so spectacular as building a dam: it is but another engineering feat; yet this is the key to the proper functioning of the entire Central Valley Project.

The building of the Contra Costa Canal goes on during the construction of Shasta Dam. Excavating machines dig their way through the dry land of Contra Costa County. Concrete covers the close-spaced reinforcing steel, making a tight lining so that there will be no water loss through seepage.

The Madera Canal was the next to be started. The building of the Friant-Kern and San Joaquin canals is to follow. In construction, the method of making these canals is pretty much the same; but each varies in size and type, depending on the water it must carry and on the topography of the country through which it runs.

The 46-mile Contra Costa Canal requires four pumping stations with five great pumps in each to boost the water from the low level of the delta up the hills to an elevation high enough so it will flow by gravity to the industrial cities and semiarid areas of Contra Costa County.

The San Joaquin Canal and Pumping System, over 100 miles in length, requires seven pumping stations to lift the surplus waters of the Sacramento River to a maximum elevation of 200 feet. At this height the force of gravity carries the water southward down the canal on the westerly side of the valley as far as Mendota.

In both the 37-mile Madera Canal and the tremendous Friant-Kern Canal, extending 160 miles into the hot, dry lands of the southern San Joaquin Valley, water from the Friant

Reservoir is to be carried along by gravity. The first section of the Friant-Kern Canal is 70 wide at the top—wider than many rivers—and 15 feet deep.

It is doubtful whether this great system of waterways will be visible from the planet Mars, but from an airplane the clean lines and blue waters will mark California indelibly in the minds of sky-crossing visitors as they look down.

Building Friant Dam

Like the construction of Shasta Dam, the work of building Friant Dam will go on day and night for several years. The men, machines, and materials are similar; only in the method of placing concrete is there much difference.

At Friant, concrete is not placed by cableway; instead, a trestle that looks like a steel bridge is used to carry cars of concrete out over the dam site. The buckets of concrete are lowered into place by big cranes that also travel on the trestle. As the blocks of concrete increase in height, the legs of this trestle are buried forever within the wall of manufactured stone.

Friant Dam, begun in November, 1939, on the upper San Joaquin River, is the fourth largest masonry dam in the world. It is a straight gravity-type dam, whereas Shasta Dam is slightly curved. Both depend on their broad bases and immense weights to hold them upright and in place. There is no power plant at Friant, and the waters of the reservoir are stored only for flood control and irrigation. Four great outlet conduits, with ponderous shut-off valves, lead through the dam to the Friant-Kern Canal; two similar conduits feed the Madera Canal; and four let water out into the San Joaquin River. As at Shasta, in times of flood, excess flows will spill over the huge central spillway and race away through the little-used San Joaquin River bed—away to the junction with the Sacramento River in the delta country, to Suisun and San Francisco bays, to the Golden Gate, and to the sea.

Although its mass is less than half as great as that of Shasta Dam, Friant's 3,430-foot length is very impressive. Compared

with the 3,500-foot-long Shasta, Friant seems more like an equal than a smaller replica.

Friant Dam (named for the founder of a near-by town), whose reservoir will flood the abandoned village of Millerton, the first seat of Fresno County, will stand on its solid foundation doing its full share of the work, holding its full share of the burden.

Between the two massive guardians of the great Central Valley—Mount Shasta to the north, and Mount Whitney to the south—the monumental evidence of man's hand and brain stretches across the land—the Central Valley Project, the most tremendous undertaking ever begun by the Bureau of Reclamation.

From statistics it can be seen that Shasta Dam is the second highest dam in the world and is also the second largest in mass-content. Boulder Dam is the highest dam in the world. Grand Coulee is the greatest dam in mass and also generates the largest amount of electric power. The San Gabriel Dam is the largest rock-fill structure. Fort Peck Dam is the largest earth-fill dam.

Yet these magnificent records of man's achievements will not stand for long. The world's greatest soon becomes the second greatest, then the third greatest, as engineers plan and workers build larger and more productive structures.

A new "world's largest dam" was partially completed and destroyed in the path of the German Army. It was the tremendous Kuibyshev Dam, being built on the Volga River in the Soviet Union. Two miles in length, with 13,000,000 cubic yards of concrete, it was built to produce an average of 15,000,000 horsepower of electric energy.

But this record, like all records, would not have stood for long. Men press forward in the application of their increased knowledge, solving greater problems in a world of expanding horizons.

Part III

THE PROJECT IN USE

JUST PRESS A BUTTON

When the Central Valley Project is completed, how will it be operated? Is it difficult to keep this far-flung quarter-billion-dollar project functioning?

No, the problem of keeping the widely separated parts working together and in good repair is hardly a problem at all. It is nearly as easy as pushing a button.

In the great Shasta and Friant dams only a few men will be needed for inspection and to operate the drum gates, outlet valves, turbines, pumps, and elevators. Only when a valve or motor wears out and must be replaced will there be a job out of the run of ordinary tasks.

How is a spring flood prepared for if it comes?

Each winter after the blanket of snow in the foothills and on the mountains has been gauged and it is known what the spring runoff of water will be, the outlet valves in the giant pipes will be opened and the water level of the reservoirs will be lowered enough to hold the flood to come. From many points on the project, along the canals and the rivers, telephone lines will lead to the control rooms of the dams. The rate of discharge into the rivers will be regulated and controlled so that no sudden dumping will flood the valley below. Normally, through the greater part of the year, the reservoirs will be only partly filled, with a maximum 237-foot rise and fall at Shasta.

All the money and materials and labor going into the building of the Central Valley Project have been spent to preserve and control and provide for man's use one valuable resource—water. Back of all the planning, the making of laws, the raising of money, are the needs which the project will fulfill: the need to overcome both flood and drought, the need for water—water in the river beds to float vessels; fresh water to hold back the salty ocean tides from creeping inland; water in reservoirs and canals to feed factories and farms; water plunging into power-

house turbines to generate electric power. And when the vast Central Valley Project is completed and the President pushes an electric button in Washington to set it into motion, it will serve these purposes, all achieved by harnessing water: irrigation, salinity control, navigation, conservation and flood prevention, and hydroelectric development.

The project, when the builders finish their work, will be the most complicated irrigation system in history. As water begins backing up behind the great dams, plunging down spillways, coursing through the canals, filling the reservoirs, the whole vast Central Valley will change in appearance. If a person could tour this broad region in an airliner, from the snowy crest of Mount Shasta in the north to the bare, brown Tehachapi Mountains in the south, he would see two huge new lakes nearly 400 miles apart, filling great valleys between steep, wooded slopes. He would see new rivers flowing where none flowed before, old rivers following new courses, dried-up rivers brought to life with fresh mountain water.

Water from the Sacramento River which has almost reached the sea will be diverted from its journey, pumped uphill for a hundred miles, and released to flow into the San Joaquin River. From Friant Dam artificial rivers will flow in two directions, a northbound river emptying into the bed of the Chowchilla River 37 miles away, a southbound river emptying into the Kern River 160 miles away. Two great dams, hundreds of miles of canals, and countless bridges, aqueducts, tunnels, siphons, powerhouses, and pumping plants will form California's first line of defense against the spectre of water famine.

The rain which falls in the wet, wooded Siskiyou and Cascade mountains of the far north will be moved all the way to the parched plains of the San Joaquin Valley in the south. And here water will again transform thirsty, dried-up fields into green acres and blooming orchards. Man will correct his mistakes of the past, and conquer the creeping menace of drought now threatening rich farm lands of central California.

OUTLET PIPES—Water stored behind Friant Dam (above) will be released into canals through big pipes like these (below) which are built into the dam. At the right are two collars for the pipes ready to be hoisted into place.

IN USE—First part of the Central Valley Project to be placed in service is the Contra Costa Canal, carrying water to industries, cities, and farms.

IRRIGATION—Water from the Canal is directed by a farmer into furrows between the rows of his vineyard.

BEFORE AND AFTER—Torn-up pieces of irrigation pipe and twiglike branches of dying orange trees (upper view) testify to the paralysis of drought in the valley. But oranges thrive (lower) when the fertile soil is adequately irrigated by water from the Central Valley Project.

INLAND NAVIGATION—By restoring reliable water depths, Shasta Dam will give new life to steamboat and barge traffic on the Sacramento River.

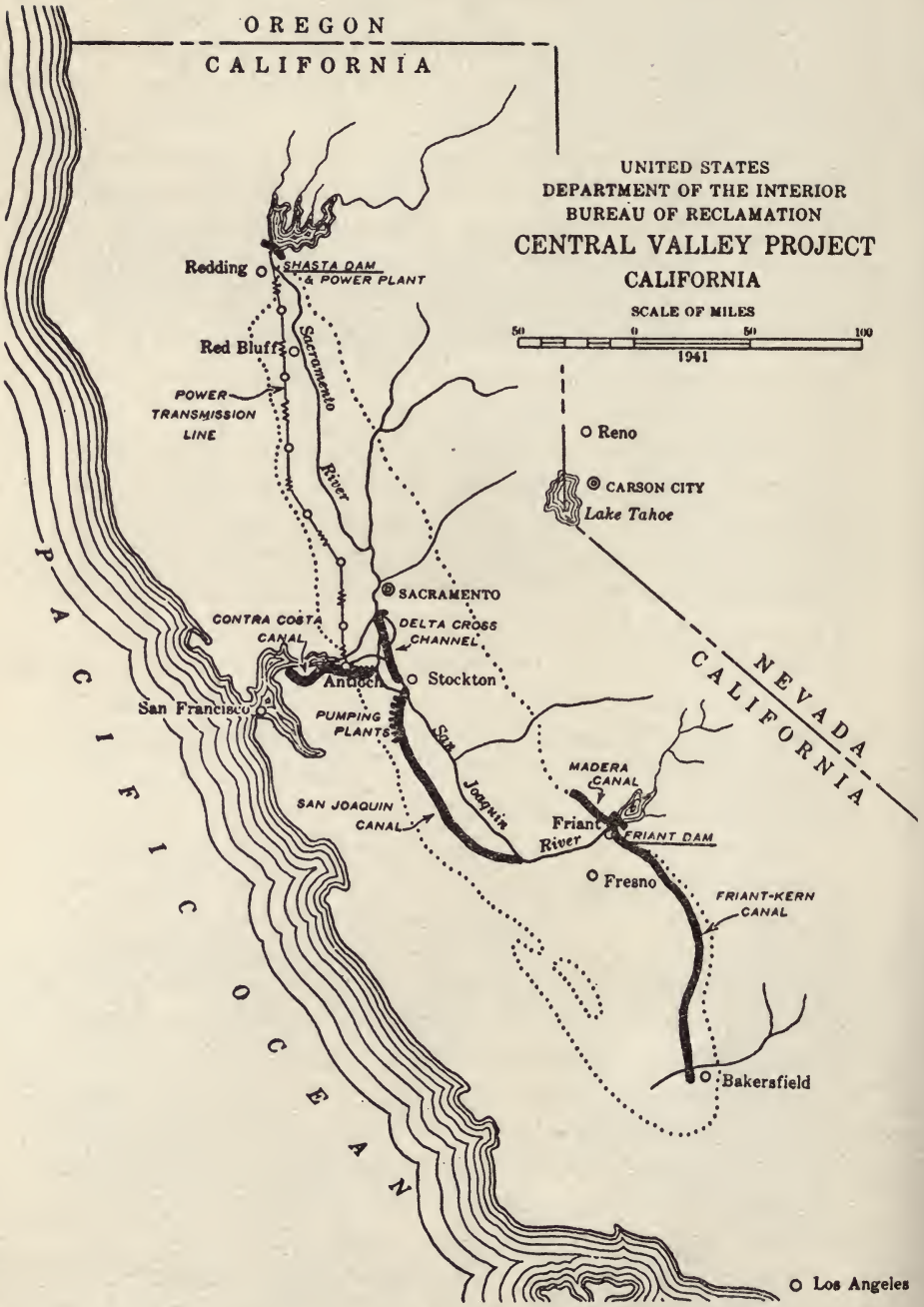
Behind Shasta Dam's wall of concrete, 560 feet high—more than twice as high as the State Capitol and higher than San Francisco's highest office building—will stretch an artificial lake almost as large as Lake Tahoe, extending back between mountain ridges for 35 miles. Into it three rivers, the Sacramento, the Pit, and the McCloud, will pour their waters. This great lake will be broad enough to float all the vessels of the United States Navy; it will be deep enough to cover the whole city of San Francisco to a depth of 167 feet. Its area will be 29,500 acres; its capacity, 4,500,000 acre-feet. In all California, only Lake Tahoe will be larger.

Friant Dam, only about half as high, damming the upper San Joaquin River, will impound less water, but still enough to create a lake 15 miles long with a 56-mile shore line, covering an area of 4,900 acres and holding 520,000 acre-feet of water. Together the two dams will be able to store up the colossal total of 5,020,000 acre-feet of water—only about a third less than all of California's 618 other dams combined.

Held in reserve behind the dams, this tremendous volume of water will be released as needed to flow through a network of canals and river-beds extending down almost the whole 500-mile length of the Central Valley.

Issuing from the draft tubes of the Shasta powerhouse, or gushing from the outlet conduits built into the dam, and sometimes cascading down the great spillway in a waterfall nearly three times as high as Niagara, the conserved waters of Shasta Reservoir will course down the Sacramento River under the control of man. Shasta Dam will serve as a monitor on the river—that is, the disastrous flood flows of winter and spring will be diminished and, correspondingly, the usually meagre runoffs of summer and fall will be augmented, thereby restoring year-round navigable depths on this important inland waterway and assuring adequate irrigation supplies for thousands of acres in the Sacramento Valley.

After Shasta's water has performed these functions and has passed every possible user on the Sacramento River, there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PUMPING
PLANTS
San
Joaquin
River
MADERA
CANAL
SAN JOAQUIN
CANAL
Friant
FRIANT DAM
Fresno
FRIANT-KERN
CANAL
Bakersfield
NEVADA
CALIFORNIA
PACIFIC OCEAN
Los Angeles

still will be a surplus for use in the Sacramento-San Joaquin Delta as well as for export to the Contra Costa area and the needy San Joaquin Valley. The water to be exported—that is, taken out of the Sacramento Valley—will be diverted at a point on the river below the city of Sacramento by another main feature of the project called the Delta Cross Channel.

RESERVOIRS AND CANALS

Water is to be pumped out of the Sacramento River into the Cross Channel, which will convey it southerly through the eastern edge of the rich delta where the two great rivers meet and mingle in a 550-mile network of interconnecting, tule-bordered, meandering sloughs and channels. Some of the fresh water in the Cross Channel will be turned out at various points to flush away the brackish, salty water that every so often creeps up into the delta sloughs from Suisun Bay. The water in the sloughs will be "sweetened," as the farmers say, so these channels can be drawn upon for irrigation of the fertile asparagus and sugar beet fields. The Cross Channel will follow the beds of some of these natural sloughs, which will be dredged and widened; in other places it is to be a dug canal.

Through it part of the Sacramento's surplus flow will be conveyed across the delta, past Stockton where another set of pumps will boost it on its way, to a point on the San Joaquin River at the southerly edge of the delta northeast of Tracy. The purposes of the Delta Cross Channel are to facilitate the freshwater flushing of the sometimes-salty waterways in the delta so as to permit full-season irrigation of crop lands there, and to introduce an adequate all-year supply of Sacramento River water to the intakes of the Contra Costa Canal and the San Joaquin Pumping System, which are the next features of the project to be considered.

The Contra Costa Canal begins at Rock Slough, which is a branch of the lower San Joaquin River, near Knightsen. Four pumping plants, spaced about a mile apart along the head end of the canal near Oakley, will raise a maximum of 350 second-feet of water in successive lifts to an elevation of 124 feet, from

which it will flow by gravity westward as far as a small terminal reservoir on Vine Hill near Martinez. The Contra Costa Canal has a diminishing capacity along its 46-mile course, in accordance with the amounts of water taken out at various points to serve a number of cities, a long string of manufacturing and processing plants, and broad acres of Contra Costa County crop lands.

The course of surplus Sacramento River water has been traced through the Cross Channel and over to a point in the San Joaquin end of the delta where some of it can be picked up by the pumps of the Contra Costa Canal. More of it will be picked up by greater pumps of the San Joaquin Pumping System which, in a sense, is the connecting link of the Central Valley Project—the feature which makes possible a better balance of water resources between the Sacramento Valley's abundant supply and the San Joaquin Valley's shortage. Six or seven pumping plants with a maximum capacity of 4,000 second-feet will be located near Tracy, boosting this water in successive lifts to an elevation of about 200 feet, from which it will flow southerly another 100 miles in a large high-line canal along the west side of the San Joaquin Valley, finally emptying into Mendota Pool on the San Joaquin River in Fresno County.

This complex system sometimes has been called "making the San Joaquin River run backwards." That is not strictly true, of course, because the regular San Joaquin River channel through that section will not be changed. However, nature's distribution of water in that area will be changed; for much of the San Joaquin's natural flow is to be cut off at Friant far upstream, and crop lands in the northern San Joaquin Valley which now are irrigated by San Joaquin River water will be given instead a substitute supply delivered by the San Joaquin Pumping System —a supply originating, it must be remembered, from the Sacramento River. This novel exchange of water in the northern San Joaquin Valley will make possible holding back the bulk of the San Joaquin River runoff at Friant Dam in the hills above Fresno, so that its precious waters can be diverted to the areas of critical irrigation need in the southern San Joaquin Valley.

So, like the Sacramento, the San Joaquin River will be transformed. No longer will it flow entirely northward toward San Francisco Bay through its old bed; most of its waters, backed up behind Friant Dam, will be turned off into new paths as unfamiliar as those which the Sacramento will follow. They will flow both north and south, but in neither direction will they find the sea.

Of all the canals in the Central Valley Project, the Friant-Kern Canal will be the largest. It has been described as a "young river" in itself. For its first 30 miles, it will be 15 feet deep, its bed 30 feet wide, and its surface 70 feet wide. With a diversion capacity of 3,500 second-feet, it will carry the San Joaquin River water from Friant Dam southward along the edge of the foothills east of Fresno, Visalia, and Tulare. At the Kings River a gigantic half-million-dollar siphon will carry the water under the Kings River. Running on southward, the flow will pass through another siphon beneath the Kaweah River. Into both the Kings and Kaweah rivers, water can be spilled to flow down their courses to Tulare Lake, for years in the process of drying up. Replenished now, it will hold water to supply farm, grain, and dairy lands surrounding it.

Below the Kaweah River the Friant-Kern Canal will turn southwestward across the flat valley floor, and west of Bakersfield it will empty its remaining waters into the Kern River through which it will drain at last into Buena Vista Lake near Taft in the valley's far southwestern corner. All the way for 160 miles along the route of the canal, through Fresno, Tulare, and Kern counties, farmers will have more water for their thirsty crops; canneries and industrial plants no longer will have to worry about water shortages; and householders can keep their lawns and gardens green and fresh. Waters of the Friant-Kern Canal will be distributed to the farms through hundreds of smaller lateral canals owned by the various irrigation districts in the southern valley.

The Madera Canal will carry 1,000 second-feet of the San Joaquin's water from Friant Dam northward along the valley's

eastern edge. Less than half as large as the Friant-Kern Canal and only a fourth as long, it will be 32 feet wide at the surface and 9 feet deep along its upper reaches, and will run for a distance of 37 miles. It too will be siphoned where it crosses the Fresno River. Turning northwestward, it will empty its waters into Ash Slough, a branch of the Chowchilla River north of Madera. From the Madera Canal, a 350-mile network of lateral canals will supply water to 170,000 acres of orchards and vineyards, cotton fields, dairy and truck farms in the Madera Irrigation District.

It is a gigantic undertaking to redistribute a large part of the water supply of a valley 500 miles long. But the benefits will be gigantic. No longer will two-thirds of the Central Valley's whole water supply run off unused to the sea. No longer will settlers in the valley's arid southern half face the threat of abandoning their parched farm lands because their local water supplies have failed. In the Central Valley as a whole at least a million acres—a third of all the valley lands now under irrigation—will be spared the effects of unequal and inadequate irrigation facilities. And not only will the thirsty farm lands receive surface water, but also the underground water reservoirs will be replenished as the new supply of water seeps beneath the surface. No longer will wells run dry or irrigation by pumping from deep wells be so expensive.

To almost every part of the great valleys the new water supply will bring its benefits, enriching lands already under cultivation, saving others from abandonment for lack of irrigation. Along the Sacramento River farmers and townspeople can count on a dependable supply the year round. The farmers will pay less for pumping charges because the river, no longer dwindling to a small stream in summer, will be kept at a more stabilized level in all seasons.

The city of Pittsburg became in August, 1940, the first community in the state to use Central Valley Project water, when its new municipal water works began receiving their supply from the Contra Costa Canal. The chemical and rubber

plants, oil and sugar refineries, paper and steel mills of Contra Costa County's great industrial belt will use millions of gallons of fresh water from the canal every day. Their boilers and other machinery will not be endangered by brine.

To the San Joaquin Valley, water will be almost as welcome as a drink to a man dying of thirst in the desert. In time, new lands may be plowed, planted, and watered—lands now left barren because of lack of water. It has been estimated that as many as 2,500,000 additional acres might be irrigated and cultivated in the Central Valley by 1970 through further conservation and control of all the water resources, such as has been begun with the Central Valley Project.

Besides irrigation, the new water supply will bring another great benefit: salinity control in the Delta area, whose rich acres lie mostly below sea level, protected by levees. When the Friant and Shasta dams are completed, controlling the flow of the rivers at a more even level all year, the river water will be high enough to hold back the ocean water.

In its first thirty-five years of existence, from 1902 to 1937, the United States Bureau of Reclamation, which is directing the construction of the Central Valley Project, built reservoirs that now irrigate a little less than three million acres of land settled by about 900,000 people. The Central Valley Project alone will provide water for more than two-thirds as many acres—about two million in all—and for more people, over a million of them, living in the Central Valley.

RETURN OF THE RIVER BOATS

It has been many years since river boats navigated upstream beyond Sacramento in the summer, many years since they sailed upstream beyond Stockton in any season. But when Shasta Dam is completed, Red Bluff, 246 miles from the mouth of the Sacramento, can be a river port again, as it was in the old days. River boating on the Sacramento will return.

To make the rivers once more navigable the year round is one of the chief purposes of the Central Valley Project. It will

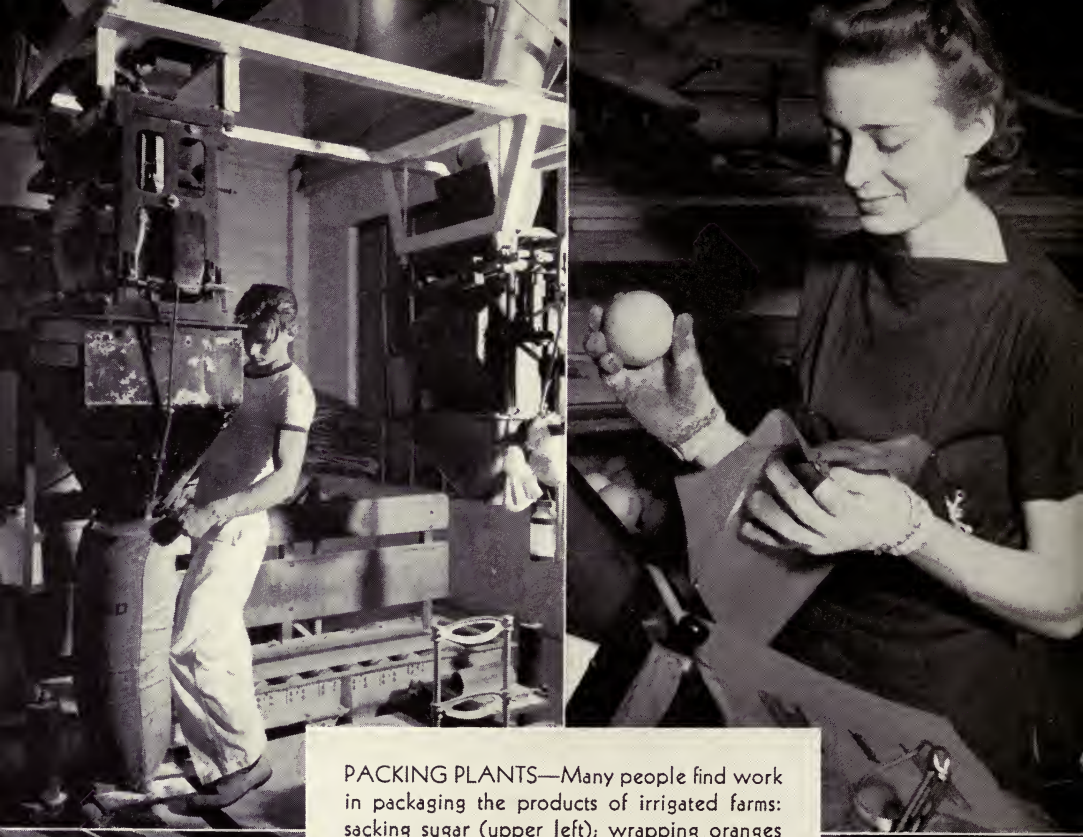
be achieved by providing a steady flow from the reservoirs. Also, navigation will be improved by dredging out parts of the river beds. Up the Sacramento River as far as the State Capital, the Army Engineers Corps already has completed a channel 10 feet deep and 150 to 200 feet wide, with the aid of wing dams and dredgers. The plans call for the maintenance of a channel 6 feet deep from Sacramento to Colusa, 5 feet deep from Colusa to Chico Landing, and as deep as practicable from Chico Landing to Red Bluff. Down this channel will pour from Shasta Dam a minimum of 5,000 second-feet of water, enough to assure navigable depths the year round. Although no plans have been made to extend navigation up the San Joaquin River beyond Stockton, partly because all the available water is so urgently needed for irrigation, the even year-round flow will aid navigation to Stockton's deep-water port; and later a navigation project may be planned to permit ships to follow the river farther upstream.

Already one of the nation's most important inland waterways, the Sacramento River will become vastly more important when the produce of the whole Sacramento Valley can be carried by water to San Francisco's warehouses and wharves. Likewise such things as oil, farming supplies, building materials, and manufactured goods will move upstream by river boat. All in all, an estimated $2,250,000 a year will be saved on transportation costs of cargo shipped between the Sacramento Valley and the San Francisco Bay region.

CONSERVATION OF NATURE'S RESOURCES

Just as the Central Valley Project will provide water in the dry season when nature has yielded too little of it, so it will hold back water in the wet season when nature has supplied too much. By harnessing the winter floods, it will not only conserve precious water which otherwise would run off to the sea; it also will conserve the soil, the timber, fish and game, fields and orchards and livestock which otherwise would be destroyed by too much water on the rampage. And so the people of the

FIELD AND FACTORY—Sugar beets are an increasingly important crop in California. Ample water makes it possible to grow them (upper view) and electric power is used to process them into pure white sugar for shipment in bags (lower) to all parts of the country.



PACKING PLANTS—Many people find work in packaging the products of irrigated farms: sacking sugar (upper left); wrapping oranges (upper right); boxing asparagus (lower left); canning olives (lower right).

RECLAMATION—Under the magic of water, dry but fertile desert (upper view) blooms into a prosperous agricultural empire (lower).

CONSERVATION—Other federal reclamation projects which serve California include Boulder Dam (upper view) on the Colorado River and Stony Gorge Dam (lower) near Orland.

Central Valley will avoid many heart-breaking losses of their vast natural riches, swept off year after year in muddy cataracts of angry flood water.

The imprisonment of the bulk of winter's flood waters behind Shasta and Friant dams will greatly decrease flood hazards in the Central Valley. The top 15 feet of Friant Reservoir will be reserved for flood storage, providing 70,000 acre-feet of storage space to absorb the flood waters. Of Shasta Dam's total storage capacity, one-ninth, or 500,000 acre-feet, will be reserved solely to impound flood waters and save them from spreading havoc below the dam.

In most seasons flood waters no longer will need to be diverted from the river channel below Red Bluff into the broad Butte Basin; instead they can be held behind the dam and the river kept within its channel. Perhaps the thousands of acres in Butte Basin may then be farmed, rather than held in reserve to absorb the river's excess flow. Below Butte Basin the river in flood season will still overflow its channel into the Sutter and Yolo by-passes, but enough water will be held back by Shasta Dam during the worst floods to prevent it from overtopping or breaking through the levees. The damage caused by a flood high enough to overflow the levees, which might thus be prevented, has been estimated at $47,000,000.

By controlling flood waters, the Central Valley Project will do more than save human beings from loss of life and property—homes, farms, highways, bridges, power lines. It will also save more helpless sufferers: fish, birds, and animals. The damage done by past floods to fish, game, and livestock has been tremendous. Fish hatcheries have been inundated and fish stranded on dry land. The high water has drowned small game birds and animals—quail, pheasant, and deer—or driven them from their natural haunts. It has carried off barnyard fowls from their roosts, cows from their pastures. But when the Central Valley Project is finished, these creatures too, both wild and tame, will be protected.

To control floods, however, dams and levees and by-passes are not enough. The watershed lands, from which pour the thousands of tiny runlets carrying rainfall down mountain gullies to unite and make a mighty river in flood, must be controlled also. For the runoff of flood waters from the mountains can be dammed, at least in part, at its source. It can be dammed by nature's own means—what foresters call ground cover, the brush and timber which hold back the water long enough for it to seep underground. When the ground cover has been cut down by ruthless logging or burned off by forest fires, then the rushing water in wet seasons races downhill, unrestrained by roots and branches, tearing away the rich topsoil and carrying it along to be deposited as silt to choke up river beds. To prevent destruction by floods and erosion, the ground cover must be replaced by replanting.

For the areas around both the Shasta and the Friant dam reservoirs, the planners of the Central Valley Project saw that watershed protection would be needed. They called on the United States Forest Service and the California State Division of Forestry to share the responsibility for providing it. To protect the 6,644 square miles of the watershed draining into the Shasta Reservoir, the Forest Service worked out a plan to replace the great forest which once covered these slopes, long ago stripped almost bare by logging, burning, and the fumes from copper-mine smelters (long since abandoned). The plan will require the planting of thousands of trees with the help of the boys of the Civilian Conservation Corps. To protect the forests from fire, government and state lookouts and guard stations, telephone stations and fire lines, new roads and trails will have to be built and maintained.

As new forests grow—and the Forest Service estimates that 52 per cent of the area will grow timber—lumbering may revive in this region, for areas now inaccessible will be reached by boats traversing the huge artificial lake. Within these watershed lands the Forest Service will encourage the pasturing of sheep and cattle as fast as the ground cover is restored to provide a

feed supply; the development of copper, gold, and silver mining; the stocking of game refuges with deer, elk, and game birds; and the establishment of summer resorts for recreation. To put this program into effect, the Forest Service recommends that the federal government buy most of the watershed lands of the Shasta drainage basin and add them to the National Forest which adjoins the area on three sides.

The very vastness of the Central Valley Project will disturb the natural habits of fish and game in the areas where it operates. Shasta Dam's huge artificial lake will stand directly in the path of the yearly migrations of deer herds to the south. Unless these wild creatures find their way around the water barrier, they will be confined north of the Pit River where the climate is severe in winter and feed conditions not of the best. It is planned to provide emergency provisions of food for these animals as well as for the small herd of elk in this region and to set aside definite areas as ranges for their welfare. The return of trees to bare regions as a result of the conservation and fire protection program will develop improved areas for upland birds, which are expected to increase in number and variety.

One of the forms of wildlife most seriously affected by the dams, pumping plants, and diversion of streams will be fish, especially steelhead and Chinook salmon. It has been estimated that twenty-five thousand Chinook salmon swim up the Sacramento River each year to spawn and die, their offspring returning downstream to the ocean. Shasta Dam will block the salmon runs which have gone up the headwaters of the Sacramento, McCloud, and Pit rivers to spawning grounds above the dam site. For years past the San Joaquin River above the Merced River has dried up in spots in the summer, thus cutting off the spawning grounds above that point. To solve this problem, it is planned to divert the salmon run up the Merced River or some lower stream. The Sacramento River situation, however, has no such simple solution. To get the fish over a dam 560 feet high—even if fish ladders such as the ones built at 60-foot Bonneville Dam were installed—would do no good, because

even if they could spawn above the dam, the young fish swimming downstream toward the ocean would be killed by the 560-foot descent.

Several plans for salvaging the salmon run have been proposed. One suggests trapping the salmon on their way upstream to the spawning grounds and transferring them to new spawning grounds in tributary streams below the dam until they learn to find these new streams. Another proposes to hold back the salmon when they have swum upstream as far as Redding, keep them in ripening ponds until they are ready to spawn, and hatch their entire crop of eggs artificially in hatcheries.

It might be possible to combine the two plans suggested: to divert some of the salmon up new streams and to hatch artificially the eggs of the rest. The first of these plans has been tried at Grand Coulee Dam, where the upstream salmon are caught in traps, lifted in elevators, dumped in thousand-gallon tank trucks, and carried overland to be released in one of four streams flowing into the Columbia River below the dam. Since the salmons' homing instinct always leads them back to the spawning grounds from which they came, this operation needs to be continued only for one generation of fish—estimated at four years for the Chinook salmon—since succeeding generations would naturally return to the new grounds. Unfortunately for the success of this plan, the Sacramento River has few satisfactory tributaries which might serve as new spawning grounds. But whatever plan is finally adopted, the salmon run will be protected if man's ingenuity can protect it.

POWER FROM WATER

To provide water—and to provide water at the right places in the right amounts—is the job which the Central Valley Project builders set out to do. But water, turning the wheels of a turbine, provides electric power. And power will light homes and run factories; power will run the motors of the project's own pumping plants; power will make possible new production for national defense. Sold to millions of users, it will bring in

money to help repay the gigantic costs of building the project. And so the Central Valley Project Act which Congress passed was written to provide "*secondarily* for the generation of electric energy."

As the base of Shasta Dam is a powerhouse, seven stories high but almost dwarfed in size by the massive concrete wall towering above it. Inside it, water rushing in through shafts from the reservoir will turn five immense turbines, each connected with an immense generator. The electricity generated here will be carried away by cables suspended from great steel pylons or towers marching 200 miles southward to a substation at Antioch on the southern shore of Suisun Bay. From here it can be distributed over a network of cables, east, west, north, and south to farms, factories, and homes anywhere between the Siskiyou Mountains and the Tehachapis, between the Pacific Coast and the Sierra Nevada.

Some time in 1944 or 1945 the turbines in the Shasta Dam powerhouse will begin turning. The generators will begin creating electric power. Working together at one time, they will produce 375,000 kilowatts of electricity. In one month they can produce from fifty to two hundred million kilowatt-hours. Over a year's time, with the aid of a steam electric plant operating when rainfall is slack, they can generate from one to two billion kilowatt-hours, an average of one and one-half billion kilowatt-hours annually.

A billion and a half kilowatt-hours of electricity would operate the trains crossing the San Francisco-Oakland Bay Bridge for 66 years; it would generate power for the bridge's illumination system for 840 years. With as much power as this, every electric iron, toaster, refrigerator, washing machine, and every other household electric appliance in the country could be operated for forty days. It would supply all the needs of San Francisco for twenty-two months, all the needs of the United States for four days.

The Central Valley Project itself will need only about one-fifth of all this power to operate its pumps on the Delta Cross

Channel, Contra Costa Canal, and San Joaquin Pumping System. The rest it will have for sale, at least a billion kilowatt-hours of electricity a year. But how will this power, increasing by about one-fifth the total output of electricity for Northern California, be distributed to the hundreds of thousands of people who will pay for it? This is a question the project builders find hard to answer.

The whole territory between the Oregon line and Bakersfield is already served by a single gigantic private power company, which sells nearly six billion kilowatt-hours of electricity a year. Three-fourths of this it generates in its own powerhouses; the other fourth it buys from other producers. Only 8 per cent of the power market in this whole territory is supplied by other power systems, and only 3½ per cent of this by publicly owned systems.

Central Valley Project power can be distributed for use in two ways: it can be sold to the great private corporation, which already sells 92 per cent of the power produced in northern California, or it can be sold to public agencies, which sell 3½ per cent. The private utility corporation has offered to buy the entire commercial output from the project. To distribute the power through public agencies, the state or federal government would have to help the people in areas where public ownership of public power is desired to form public utility districts to buy and sell the project's output.

The people who favor distributing public power by selling it to a private company argue that public utility districts would have to construct their own distribution lines. These might duplicate lines already built by the private system. Or, if the movement for public ownership grew strong enough, it might lead to the cancellation of franchises granted to the private system and to confiscation of its transmission lines by public agencies.

On the other hand, the advocates of public ownerhsip of power argue that it will benefit the people, in spite of the expense of constructing facilities, because it will reduce the price of

electricity. As the money invested in building the system is paid off, rates can be lowered constantly. The advocates of public ownership also argue that northern California's great private power corporation has opposed the Central Valley Project from the beginning, and they argue that it has opposed the organization of public utility systems throughout the Central Valley. Governor Culbert L. Olson agreed with the believers in public ownership when he said in his inaugural address: "It shall be the purpose of this administration to promote the means for public ownership and operation of plants and distributive facilities for the distribution of this electric power for the people at cost."

The man under whose direction the vast Central Valley Project is being built, Secretary of the Interior Harold L. Ickes, stated his belief in the governmental control of electric power in an address which he gave at Friant Dam when work was begun in November, 1939: "What has been accomplished here in California, and elsewhere, in the way of great public works illustrates the value of intelligent co-operation between the national, state and local governments . . . . This is a line of creation, built to unlock the fertility of the rich soil, to resist drought, to overcome floods, to provide outdoor recreation, and to generate cheap power that will lighten the labors and improve the living conditions of millions of our citizens."

In a meeting with representatives of the federal government on September 8, 1940, the State Water Project Authority decided that its policy should be to help form and finance public distribution systems to distribute Central Valley Project power. "I think a great amount of good will result," said United States Commissioner of Reclamation John C. Page, "if the Authority steps out aggressively and lets the people know that it is now in a position to give assistance to districts desiring Central Valley Project power. This move will grow like a snowball rolling downhill . . ."

On both sides in the controversy between public and private ownership, constant warfare of words and legal conflict

goes on. But few people believe that undertakings so vast as the great dams and irrigation projects built throughout the nation during the last few years could ever have been built by private industry. For private industry could not have invested the huge sums necessary for their construction without hope of immediate profit. Only the federal government can wait the long years which will pass before these mammoth construction projects will be paid for.

GAINS FOR THE PEOPLE

When the Central Valley Project's two immense new lakes appear on the map of California, the people of the state will have for their enjoyment two new mountain recreation centers. Overlooking the lakes, people can build cabins, resorts, campgrounds, and summer homes. The reservoir waters, stocked with game fish, will attract fishermen; on their placid surfaces, people can enjoy swimming, canoeing, rowing, sailing. Hikers and hunters can ramble over the surrounding slopes. Under the jurisdiction of the National Park Service, camping and picnicking grounds will be developed, new summer resorts established, roads and trails laid out.

If the Shasta and Friant dams rival Boulder Dam, which is visited yearly by a half million people, as tourist attractions, they should become two of California's most popular sites for visitors. Already California has more national parks than any other state. With two new areas to draw vacationers and visitors from all over the nation, it should profit from a new stimulus to tourist trade. When these man-made spectacles are added to that great circuit of the West's wonders that lies between the Grand Canyon of the Colorado in the Southwest and Bonneville and Grand Coulee dams in the Northwest, the traveler by automobile will be able to make a magnificent tour, swinging in a great half-circle from Arizona to Washington, past Boulder Dam, Death Valley National Monument, Sequoia National Park, Friant Dam, Yosemite National Park, Lake Tahoe, Mount Lassen Volcanic National Park, Shasta Dam, and Mount Shasta.

But the people will gain much more than new recreation centers and increased tourist trade. The completed Central Valley Project will help agriculture, business and industry, finance, the trades and professions. Up and down the state, people in all walks of life will benefit in health, happiness, and security.

As the network of canals spreads water stored up by the vast dams throughout the valleys and the land is restored to fertility, it is predicted that those who have left the land will come back, that new farms will be created and new acres tilled, that farm products will increase in volume, and land values will rise. Acres already planted will be saved; farmers already growing crops will be protected. And as the farms benefit, so will the cities. It has been estimated that Los Angeles and San Francisco alone will save the vast sum of $22,000,000 a year by maintaining wholesale and manufacturing trade with the valleys, which would have been lost if water-starved farms had to be abandoned.

Little did the forty-niners who came to California to look for gold realize that the day would come when water would be more precious than any metal. They found a virgin country, its natural balance undisturbed. The spring floods of the two great rivers overflowed their banks and soaked the bordering flat lands, creating vast marshes. As the country was developed, more and more water was diverted for irrigation and more and more marshland reclaimed for agriculture. The natural balance was upset. When there was not enough river water left, wells were dug. When wells went dry, they were dug deeper. The underground water levels went on falling.

The vanishing water supply began to threaten the very sources of life and property of millions of people. Farms, industrial plants, whole great cities were menaced. Only water could save them from the fate of other regions where man's carelessness in plowing up the grasslands and draining the marshes, cutting and burning down the timber on the slopes, choking up the rivers with silt from hydraulic mines had upset nature's delicate bal-

ance. Only water could save vast stretches of California's Central Valley from the fate of the Middle West's Dust Bowl.

In few places has man made more changes in his surroundings than in California. Sometimes the changes have been for the better, sometimes for the worse. When they were dictated only by greed—when man wanted only to rob nature of its riches by blind and unthinking use of the soil, the water, the timber, the minerals, the fish and game, without caring about future generations and their needs—then his changes were for the worse. But man can repair his mistakes of the past. He can even improve on nature—and so the Central Valley Project will demonstrate to those now living and to generations to come.

Appendix I

OUTLINE FOR A UNIT OF WORK FOR THE UPPER GRADES

OUTLINE FOR A UNIT ON THE CENTRAL VALLEY PROJECT

This outline for a unit on the Central Valley Project which follows was prepared by students in Education 133, Section III, during the 1940 Summer Session at the University of California, Berkeley. This group of teachers endeavored to explore and to record all of the possibilities inherent in this area of experience. It is unlikely that any group of children can undertake all of the activities suggested. Teachers will find this comprehensive and practical outline a useful source in their preparation for guiding the learning experiences of the children.

The great geographic extent of the project will make possible valuable firsthand experiences for many children from Shasta County to Kern County. Other children may have direct contact through summer vacation trips. The extensive illustrations in the bulletin will provide the basis for a realistic vicarious experience.

I. Factors Considered in Selecting the Unit

A. The immediate life of a large number of children of California will be affected

B. Unique and comprehensive utilization of natural resources is illustrated by the project

C. As an example of democratic enterprise for the welfare of a region, the study should lead to a genuine appreciation of the services of the federal, state, and local government

D. The area of experience will help children understand the complexity of our modern technological and scientific era

E. The area of experience will help children understand and appreciate the variety of services and the number of workers needed in such a vast undertaking; the social and economic problems of the workers

F. The area of experience will provide opportunity for firsthand contact with life situations and will satisfy the basic urges or drives to

learning, such as curiosity, construction, dramatic play, creative expression, manipulation, and communication

G. The area of experience provides ample opportunity for using the tools of learning

II. Initiation of Unit

A. Alternative ways of introducing the unit

1. By exploration of classroom environment arranged by the teacher

a. Pictures

(1) River in flood
(2) Shasta Dam and other dams
(3) Cement "silo"
(4) River boats
(5) Dredges
(6) Power plants
(7) Productive and arid farms

b. Maps

(1) California
(2) United States

c. Books
d. Models
e. Wood for construction purposes
f. Tools
g. Cable
h. Hard shell hat
i. Newspaper clippings
j. Magazines
k. Pamphlets

l. Toys

(1) Power shovels
(2) Trucks
(3) Tractors
(4) Trains
(5) Dragline
(6) Pneumatic hammers

m. Cement

2. By showing slides or motion pictures of the Central Valley Project
3. By means of a discussion of the experience of a child who visited the project, or experienced a flood, or who had migrated from an arid farm
4. Reading a selection or story, such as *Water—Wealth or Waste,* by William Pryor

B. By class discussion
1. Why do we build dams?
2. How are dams built?
3. Why do the workers wear hard-shell hats?
4. What causes floods?
5. Where is the nearest dam?
6. Is it possible to take a trip to the project?

C. By reading to answer questions raised in the discussion

D. By planning the excursion

III. Development of Unit

A. Find out units of project
1. Shasta Dam
2. Friant Dam
3. Contra Costa Canal
4. Madera Canal
5. Kern Canal
6. Pumping station
7. Transmission lines
8. Power plant
9. Railroad and highway construction

B. Purposes of the units, irrigation, flood control

C. Locate various units

D. Read books, pamphlets, clippings, stories, poems

E. Write letters about trip and for material

F. Listen to an informed person concerning history of the area, construction of the units of the project

G. See slides or motion picture

H. Go on trip
   1. Develop safety plans
   2. Develop conduct rules
I. Play with blocks and toys
J. Relive by means of dramatic play
   1. Life of workers
   2. Life of pioneers
   3. Life of people in flood time
   4. Life of the farmers
K. Write stories, poems, letters, and songs
L. Develop rhythms
M. Paint
N. Model

IV. Experiences in Which Teacher and Children May Engage
A. Search for information by reading
B. Art Experiences
   1. Construction
      a. Relief map
      b. Outline map
      c. Truck, people, and the like, for play
      d. Community at dam
      e. Make and dress standpatter dolls
      f. Model of irrigation system
      g. Models of arid and productive farms
      h. Models of power plants and power lines
      i. Models of conveyor belt
      j. Models of boats
      k. Models of tunnels
      l. Models of bridges
         (1) For trains
         (2) For highways
      m. Model of rock crusher
      n. Model of concrete mixer
      o. Model of "head tower," "tail tower," cableways
      p. Blueprint (plan of model)

2. Graphic Art
   a. Friezes and panels
      (1) History of the Central Valley
      (2) Central Valley water project
      (3) Arid and productive farms
      (4) River commerce

   b. Drawing and painting pictures
      (1) Illustrations for stories
      (2) Impression of experiences
      (3) Sources and uses of water

   c. Notebook covers

   d. Lettering
      (1) Notebook covers
      (2) Captions for displays and bulletin boards

   e. Posters
   f. Arranging bulletin boards
   g. Block printing
   h. Slides
   i. Motion picture strips

3. Photography

C. Dramatic Play
   1. Reliving the life of workers
      a. Concrete workers
      b. "High scalers"
      c. "Powder monkeys"
      d. Planners
      e. Surveyors
      f. Engineers
      g. Drillers

   2. Reliving the life of farmers
   3. Recreating experiences during floods
   4. Enacting scenes from river life
   5. Enacting scenes from life related to history of region

D. Language Experiences
   1. Oral
      a. Conversation
      b. Discussion
      c. Dramatization of stories
      d. Radio scripts or plays
      e. Oral reports
      f. Interviews
      g. Participating in school club
      h. Dramatic play
   2. Written (individual or group activities)
      a. Letter
         (1) Inviting guest speaker
         (2) Requesting materials or information
         (3) Requesting permission to visit
         (4) Requesting parents' permission to go on trip
         (5) Inviting parents or friends to school or special program
         (6) Letters to friends telling about study
      b. Stories
         (1) Co-operative stories
         (2) Imaginative stories
         (3) News stories
      c. Plays
      d. Radio scripts
      e. Poems
      f. Log of progress of unit
      g. Reports
      h. Captions for pictures
      i. Labels for exhibits
      j. Notices for bulletin boards
      k. Book
         (1) New and effective words
         (2) Spelling lists
         (3) Diaries
         (4) Scrapbooks
      l. Minutes of club meetings

E. Music Experiences
   1. Singing (see bibliography, page 159)
   2. Creative music
   3. Bands and orchestras
      a. Harmonic
      b. Rhythm

F. Specific Learning Experiences
   1. Reading
      a. Information
      b. Solve problems
      c. Pleasure
      d. Use of bibliography
      e. Reference books
      f. Dictionaries
      g. Tables of contents
      h. Globes
      i. Blueprints
      j. Graphs
      k. Diagrams
   2. Arithmetic
      a. Compute cost
      b. Measure distances
         (1) Measuring electricity
         (2) Measuring rainfall
      c. Areas
      d. Content
      e. Time
      f. Proportion
      g. Financing
      h. Profit and loss
      i. Acre-feet of water
      j. Graph making
      k. Blueprinting.

3. Language Arts
   a. Spelling
   b. Penmanship
   c. Oral expression
   d. Organize information
   e. Letter writing
   f. Report writing
   g. Plays
   h. Stories

4. Social Studies
   a. Function of government
      (1) Local
      (2) State
      (3) National
   b. Topography of country
      (1) Firsthand experience
      (2) Map
   c. California history
   d. Social problems of workers
      (1) Employment
      (2) Health and sanitation
      (3) Safety
      (4) Housing
      (5) Recreation
      (6) Education

G. Appreciations
   1. Books
   2. Storytelling
   3. Music and songs
   4. Poetry
   5. Dramatic play and rhythm
   6. Visual aids
   7. Art
   8. Nature

9. Contribution of workers
   a. Laborers
   b. Mechanics
   c. Engineers
   d. Others
10. Government

V. Anticipated Outcomes

A. Basic Understandings

1. An appreciation of the difficulties of life without water control
2. An appreciation of the need for conserving waste water
3. An understanding of the effort required to obtain adequate water supply
4. An appreciation of the resources in nature that make water supply possible
5. A respect for the contribution of science in the development of building materials
6. A consciousness of the facilities for conservation of water supply in the community
7. An understanding of the effect of water on the surrounding country

B. Basic Knowledges Gained

1. Topography of the country
2. Better knowledge of the uses of water
   a. Irrigation
   b. Power
   c. Transmission
   d. Drinking
   e. Recreation
3. The sources of water
4. Protection against floods
5. Contrast of conditions of life in early California days with those of the present in regard to transportation, navigation, industries, and irrigation
6. An understanding of how water led to the exploration and settlement of California

C. Social Habits
   1. Ability to work well together
   2. Ability to think independently
   3. Ability to contribute to discussions
   4. Courteous consideration of others
   5. Ability to use materials
   6. Ability to accept suggestions

D. Increased Skills
   1. Ability to observe intelligently
   2. Ability to recognize problems
   3. Ability to use information from a variety of sources
   4. Ability to appreciate the value of co-operative planning and execution of work
   5. Ability to express thoughts and feelings in many ways, such as writing, painting, play, rhythm
   6. Ability to read with understanding and enjoyment
   7. Ability to speak English well
   8. Ability to spell words needed
   9. Ability to use tools correctly
   10. Ability to measure and plan

E. Appreciations
   1. Books
   2. Experiences
   3. Stories
   4. Pictures
   5. Models
   6. Work of others
   7. Music
   8. Poetry
   9. Rhythms
   10. Nature
   11. Visual materials
   12. Contribution of the workers
   13. Government

CHILDREN'S REFERENCES

Books

BEATY, JOHN. *Story Pictures of Farm Work.* Chicago: Beckley-Cardy Co., 1936, pp., 111-121 (1-2).

BEAUCHAMP, WILBUR. *Science Stories.* Books 2 and 3. Chicago: Scott, Foresman & Co., 1935, pp., 117-119 (2-3).

CHARTERS, W. W., and OTHERS. *From Morning Till Night.* New York: The Macmillan Co., 1936, pp., 12-14; 53-56 (1-2).

CHARTERS, W. W. *Good Habits.* New York: The Macmillan Co., 1935, pp., 102-106 (3+).

CHARTERS, W. W. *Happy Days.* New York: The Macmillan Co., 1936, pp., 86-87 (2-3).

CRAIG, GERALD. *Our Wide, Wide World.* Boston: Ginn & Co., 1932, pp., 237-253; 273-279 (3+).

CRAIG, GERALD. *Out of Doors.* Boston: Ginn & Co., 1932, pp., 180-182 (2-3).

CRAIG, GERALD. *We Look About Us.* Boston: Ginn & Co., 1933, pp., 78-86 (1-2).

DAWSON, GRACE S. *California: The Story of Our Southwest Corner.* New York: The Macmillan Co., 1939 (6, 7, 8).

DOUGHERTY, ETHEL. *How the World Drinks.* Science and Safety Series, Crawfordsville, Indiana: R. R. Alexander and Sons, 1936 (5).

EDWARDS, PAUL. *Outdoor World.* Boston: Little, Brown & Co., 1932, pp., 172-174 (3+).

FAIRBANKS, H. W. *Conservation Reader.* New York: World Book Co., 1920, pp., 10-11; 81-88 (6).

Find Out Book. Vol. 2. Chapel Hill, North Carolina: University of North Carolina Press, 1937 (3).

GLOVER, KATHERINE. *America Begins Again. The Conquest of Waste in Our Natural Resources.* New York: McGraw-Hill Book Co., 1939 (6, 7, 8).

HOLWAY, HOPE. *Story of Water Supply.* New York: Harper & Bros., 1929 (6).

LULL, MARGARET. *Golden River.* New York: Harper & Bros., 1930.

Fiction for older girls about the Sacramento River.

PATCH, EDITH M. *Surprises.* New York: The Macmillan Co., 1933, pp., 173-194 (3+).

PERSING, ELLIS. *Elementary Science by Grades. Book* 2. New York: D. Appleton & Co., 1928, pp., 163-168 (2-3).

PIEPER, CHARLES JOHN. *Everyday Problems in Science.* Chicago: Scott, Foresman & Co., 1933.

Chapters 5, 9, 10 give the sources of water supply, showing how water is purified for domestic use, and how heat is controlled and used for heating purposes.

PIGMAN, AUGUSTUS. *A Story of Water.* New York: D. Appleton-Century Co., Inc., 1938 (6-7).

PRYOR, WILLIAM CLAYTON. *Water—Wealth or Waste.* New York: Harcourt, Brace & Co., 1939 (5).

Good print, excellent pictures.

RINGER, EDITH H. *Good Citizens Club.* Philadelphia: J. B. Lippincott & Co., 1930, pp., 66-69 (3).

ROGERS, FRANCES. *Fresh and Briny. The Story of Water as Friend and Foe.* New York: Frederick A. Stokes Co., 1936 (6, 7, 8).

A useful and excellent account.

STONE, CLARENCE. *Joyful Reading.* St. Louis, Missouri: Webster Publishing Co., 1932, pp., 21-23 (2).

THOMPSON, JEAN M. *Water Wonders Every Child Should Know.* New York: Doubleday, Page & Co., 1907 (5-6).

TEACHERS' REFERENCES

BOOKS

ADAMS, FRANK. *Irrigation Districts in California.* State of California, Department of Public Works. Bulletin No. 21, 1929. Sacramento: State Department of Public Works.

BRISTOW, WILLIAM H. *Conservation in the Education Program.* U. S. Office of Education Bulletin No. 4, 1937, Washington: United States Department of the Interior, 1938.

"Thirst Quencher Number One," *Consumer's Guide.* IV (July 12, 1937), 16-17.

An analysis of the physiological need for water. The importance of water to the human body. Factual.

FLINN, ALFRED D.; WESTON, R. S.; and BOGERT, C. L. *The Waterworks Handbook.* New York: McGraw-Hill Book Co., Inc., 1927. Technical.

FOLWELL, A. PRESCOTT. *Water Supply Engineering.* New York: John Willey & Sons, 1917.

GELDERS, JESSE F. "Miracles Worked by Engineers in Endless Fight for Water," *Popular Science,* CXIX (October, 1931), 42-43; 141-143.

An excellent article outlining man's struggle for water, and describing methods used by engineers in modern and ancient cities to obtain it.

HOOVER, MILDRED B. *Historic Spots in California: Counties of the Coast Range.* Stanford University, California: Stanford University Press, 1937.

HUNT, ROCKWELL. *California: A Little History of a Big State.* Boston: D. C. Heath & Co., 1931.

HUNT, ROCKWELL. *California the Golden.* Boston: Silver, Burdett & Co., 1911.

JACKS, G. V. *Vanishing Lands.* New York: Doubleday, Doran & Co., 1939, pp., 192-203.

JAMES, GEORGE W. *Reclaiming the Arid West.* New York: Dodd, Mead & Co., 1917.

Story of the United States Reclamation Service.

LOMAX, JOHN A., and LOMAX, ALAN. *Cowboy Songs.* New York: The Macmillan Co., 1922.

MACLEISH, ARCHIBALD. *Land of the Free.* New York: Harcourt, Brace & Co., 1938.

MATHEWS, J. L. *Conservation of Water.* Boston: Small Maynard & Co., 1910.

Although published in 1910, this publication gives a clear, precise presentation of the many problems connected with water use and conservation. Presents the benefits to be gained from the control and planned use of the national water resources.

PERSON, H. S. *Little Waters: A Study of Headwater Streams and Other Little Waters, Their Use and Relation to the Land.* Washington: Soil Conservation Service: Resettlement Administration; Rural Electrification Administration (rev. April, 1936).

This tells simply, with many pictorial graphs and illustrations, the effects of the control of little waters—creeks, rills, ponds, headwater streams, and their relation to the land.

RENSCH, HERO E., and RENSCH, E. G. *Historic Spots in California: The Southern Counties.* Stanford University, California: Stanford University Press, 1932.

RENSCH, HERO E., and RENSCH, E. G. *Historic Spots in California: Valley and Sierra Counties.* Stanford University, California: Stanford University Press, 1933.

Sacramento Guide Book. Sacramento, California: The Sacramento Bee, 1939.

SHERWIN, STERLING, and KATSMAN, LOUIS. *Songs of the Gold Miners.* Cooper Square, New York: Carl Fischer, 1932.

SMITH, WALLACE. *Garden of the Sun.* Los Angeles: Lymanhouse, 1939.

A history of the San Joaquin Valley, 1772 to 1939.

WAGNER, HARR, and KEPPEL, MARK. *Lessons in California History.* San Francisco: Harr Wagner Publishing Co., 1922.

PERIODICALS

United States Camera Magazine. Travel Issue (August, 1940), 30, 49, 82, 84.

California History Nugget, "The Story of the Pit River," VII (March, 1940), 171-179.

APPROPRIATE MUSIC FROM AVAILABLE COLLECTIONS

MCCONATHY, OSBOURNE, and OTHERS. *The Music Hour.* California State Series. Sacramento: California State Department of Education, 1931.

Third Book

Bach	"The Water Dance," p., 53
Olds	"The Rainbow Fairies," p., 78
Lilly	"Song of the Snows," p., 76
Folk Song (Czecho-Slovak)	"The Old Man," p., 69

Fourth Book

Schubert	"Boatman's Song," p., 89

Fifth Book

Bach	"The Hidden Stream," p. 23

Kindergarten and First Grade Music Book

Findlay	"The River," p., 118

McConathy, Osbourne, and Others. *Music of Many Lands and Peoples.* California State Series. Sacramento: California State Department of Education, 1932.

Adapted by Buck	"Volga Boat Song," p., 174
Old English Round	"A Boat, A Boat," p., 120
Old Sailor Chantey	"Blow the Man Down," p., 143

Parker, Horatio, and Others. *Progressive Music Series.* New York: Silver Burdett & Co., 1918.

Book One

Weidig	"The River," p., 87
Sanne	"Paper Boats," p., 92

Book Two

Doring	"The River," p., 124
Wathall	"The Way the Rain Behaves," p., 55

Book Three

Bliss	"Song of the Brook," p., 66
Chadwick	"The Rain Path" (Two Parts), p., 130
Elgar	"The Brook" (Two Parts), p., 130
Russian Folk Song	"Maid and the Brook," p., 25.

Twice 55 Plus Community Songs, The New Brown Book. Boston: C. C. Birchard & Co., 1929.

"Row, Row, Row Your Boat"
"Levee Song"
"Flowing River"

Other Appropriate Music

Strauss	"Blue Danube"
Russian Folk Song	"Volga Boat Song"
Foster	"Swanee River"
Kern	"Old Man River"
Cadman	"Land of the Sky Blue Water"
Lieurance	"By the Waters of the Minnetonka"
Schubert	"The Trout"
Weber	"The Storm"
Mendelssohn	"Boat Song"
Dukas	"Sorcerer's Apprentice"
Wagner	"Songs of the Rhinedaughters"
Ravel	"Jeu d' Eaux"
Smetana	"La Moldau"
Respighi	"Fountains of Rome"
Handel	"Water Music"
Wagner	"Siegfried's Rhine Journey"
Schubert	"Songs to be Sung on the Water"
Lehmann	"The Pine Trees"

Appropriate Paintings

Hagen	"Meister der Farbe"
Martin	"Harp of the Winds"
Van Gogh	"The Bridge"
Monet	"The Poplars"
Daubigny	"The Pool"
Daubigny	"Valmondois"
Maure	"In the Pasture"
Jones	"Chums"
Inness	"Autumn Oaks"
Bellows	"Up the Hudson"

Appendix II

SOURCE MATERIAL

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Books

California, A Guide to the Golden Gate. Federal Writers' Project of the Works Progress Administration for the State of California. New York: Hastings House, 1939.

Chamberlain, William H. *History of Yuba County.* Oakland, California: Thompson and West, 1879.

Davis, William J. *An Illustrated History of Sacramento County, California.* Chicago: Lewis Publishing Co., 1890.

The Drama of Cement Making. Chicago: Portland Cement Co., 1938.

Elias, Sol. P. *Stories of Stanislaus.* Modesto, California: Sol. P. Elias, 1924.

Ellis, W. T. *My Seventy-Two Years in the Romantic County of Yuba, California.* Eugene, Oregon: University of Oregon, 1939.

Fenneman, Nevin M. *Physiography of Western United States.* New York: McGraw-Hill Book Co., Inc. 1931.

Fletcher, Gustav L. *Earth Science, A Physiography.* Boston: D. C. Heath & Co., 1938.

Gilbert, Frank T. *History of San Joaquin County, California.* Oakland, California: Thompson and West, 1879, 2 vols.

History of Stanislaus County, California. San Francisco: Wallace W. Elliott & Co., 1883.

Hunt, Rockwell D., and Ament, William S. *From Oxcart to Airplane.* Los Angeles: Powell Publishing Co., 1929.

Mikhailov, Nicholas. *Land of the Soviets.* New York: Lee Furman, 1939.

Norris, Frank. *The Octopus.* New York: Doubleday, Page & Co., 1901.

Ransome, Frederick Leslie. *The Great Valley of California.* University of California Publications in Geological Sciences, Vol. I, No. 14, pp. 371-428. Berkeley: University of California Press, May, 1896.

Schuyler, James Dix. *Reservoirs for Irrigation, Water-Power and Domestic Water Supply.* New York: John Wiley & Sons, 1908.

Small, Kathleen Edwards. *History of Tulare County, California.* Chicago: S. J. Clarke Publishing Co., 1926. 2 vols.

Smith, Wallace. *Garden of the Sun, A History of the San Joaquin Valley, 1772-1939.* Los Angeles: Lymanhouse, 1939.

Wegman, Edward. *The Design and Construction of Dams.* New York: John Wiley & Sons, 1922.

State and Federal Government Publications

Bradbury, J. K., and Barnum, N. M. "Land Use Study of the Kennett Area." Washington: United States Department of Agriculture, Forest Service. January 4, 1938 (mimeographed).

"Central Valley Project." Washington: United States Department of the Interior, Bureau of Reclamation. n.d.

"General Information Concerning the Central Valley Project, California." Washington: United States Department of the Interior, Bureau of Reclamation, March 1, 1940 (mimeographed).

The Grand Coulee Dam and the Columbia Basin Reclamation Project. Washington: United States Department of the Interior, Bureau of Reclamation, n.d.

"The Grand Coulee Dam: The Columbia Basin Reclamation Project." Washington: United States Department of the Interior, Bureau of Reclamation, n.d. (Folder).

FORTIER, SAMUEL, and OTHERS. *Irrigation in the Sacramento Valley, California.* Experiment Stations Bulletin No. 207. United States Department of Agriculture. Issued February 15, 1909.

"The History of the Central Valley Project." Sacramento: United States Department of the Interior, Bureau of Reclamation, February, 1941 (mimeographed).

"Memorandum by Edward Hyatt, State Engineer and Executive Officer on Necessity of an Auxiliary Steam-Electric Plant as a Unit of the Central Valley Project." Reports on Electric Power, Central Valley Project, Water Project Authority of the State of California. Sacramento: Department of Public Works, May 15, 1940 (mimeographed).

"Output Capacity of Shasta Power Plant under Alternate Methods of Disposal." Report No. 1. Reports on Electric Power, Central Valley Project, Water Project Authority of the State of California. Sacramento: Department of Public Works, July, 1940 (mimeographed).

Permissible Economic Rate of Irrigation Development in California. A Co-operative Report by the College of Agriculture, University of California. Reports on the State Water Plan Prepared Pursuant to Chapter 832, Statutes of 1929. Bulletin No. 27. Publications of the Division of Water Resources. Sacramento: State of California Department of Public Works, Division of Water Resources, 1931.

Proceedings of the Second Sacramento-San Joaquin River Problems Conference and Water Supervisor's Report. By Harlowe M. Stafford, Water Supervisor. Bulletin No. 4. Sacramento: State of California Department of Public Works, Division of Water Resources, 1925.

"Report on the Programming of Additional Electric Power Facilities to Provide for Absorption of Output of Shasta Power Plant in Northern California Market." Reports on Electric Power, Central Valley Project, Water Project Authority of the State of California. Sacramento: Department of Public Works, February, 1928 (mimeographed).

SCOBEY, FREDERICK C. *Flow of Water in Irrigation and Similar Canals.* Technical Bulletin No. 625. Washington: United States Department of Agriculture. February, 1909.

"The Story of the Central Valley Project of California." Sacramento: Presented by the Water Project Authority of the State of California. n.d. (Folder).

Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay. Reports on the State Water Plan Prepared Pursuant to Chapter 832, Statutes of 1929. Bulletin No. 27. Publications of the Division of Water Resources. Sacramento: State of California Department of Public Works, Division of Water Resources, 1931.

MAGAZINE ARTICLES

SMITH, OSGOOD R. "Fact Finding Survey in the Sacramento Drainage Basin," *Associated Sportsman,* V (October, 1938).

California Conservationist. Sacramento: California Department of Natural Resources.

CLARK, G. H. "The Future of Fish Life in the Central Valley," IV (May, 1939), 1, 16.

GLADING, BEN. "California Valley Quail," IV (January, 1939), 3-6.

CLARK, FRANK W. "Review of State Public Works Program," *California Highway Patrolman,* III (May 19, 1939), 6, 7; 68-70.

California Highways and Public Works. Sacramento: California Department of Public Works.

"Central Valley Project," XVI (August, 1938), 2-6.
"Central Valley Project," XVII (November, 1939), 27.
"Contra Costa Canal Project Illustrated," XVIII (January, 1940), 2, 3.

HYATT, EDWARD. "Division of Water Resources Official Reports," XV (February, 1937), 24, 25.

HYATT, EDWARD. "Three Central Valley Project Milestones," XVIII (August, 1940), 3-5; 20.

PURCELL, C. H. "State Joins United States in $3,200,000 Contract for Highway Relocation Around Shasta Dam Reservoir," XVII (November, 1939), 1-4; 16.

"Shasta Dam Aggregate Belt Conveyor Longest in the World," XVIII (February, 1940), 2-4.

"State Adopts a Three-Point Program for Marketing Power of the Central Valley Project," XVIII (October, 1940), 1-5; 19.

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